CEE review 05-015

ARE JAPANESE KNOTWEED (FALLOPIA JAPONICA) CONTROL AND ERADICATION INTERVENTIONS EFFECTIVE?

Systematic Review

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SYSTEMATIC REVIEW SUMMARY

Background

Japanese knotweed (*Fallopia japonica*) is an invasive plant listed as one of the IUCN's top 100 invasive species of global concern. It is a vigorously competitive plant that regenerates readily, and is difficult to control. Japanese knotweed control and eradication is undertaken using a wide suite of mechanical and chemical techniques. Many statutory and non-statutory agencies publish guidelines detailing the effectiveness of various methods, but a critical appraisal of empirical evidence regarding the effectiveness of different control and eradication methods has not previously been undertaken. The need to evaluate control and eradication methods under a variety of circumstances and time periods has been identified by UK stakeholders, but has global relevance.

Objectives

To systematically collate and synthesise published and unpublished evidence in order to address the question:

> "Are Japanese knotweed (*Fallopia japonica*) control and eradication interventions effective?"

The secondary objective was:

> "To investigate whether effectiveness of control and eradication treatments for Japanese knotweed is influenced by the following factors:
> 1. Environmental and geographical factors;
> 2. Operational level variables; and
> 3. Hybridisation and species variety."

Search strategy

Electronic searching was completed using the following databases, catalogues and web-engines: Agricola, CAB Abstracts, Digital Dissertations Online, Index to Theses Online, ISI Web of Knowledge (including ISI Web of Science and ISI Proceedings searches), JSTOR, Science Direct, Scirus (all journal sources), Scopus, AllTheWeb, Dogpile, Google Scholar, Scirus (all web sources), Blackwell Synergy, ConservationEvidence.com, Copac, Directory of Open Access Journals, English Nature's "Wildlink" library catalogue, Elsevier, European Nature Information System database V2 (EUNIS), iSpecies, and SpringerLink. Publication searches on 49 statutory and non-statutory organisation websites were conducted. Specialist searching was completed on 14 invasive species websites. Bibliographies of articles accepted into the review, traditional literature reviews, and relevant literature lists were searched for additional articles. Personal contact with researchers was used to retrieve further data.

Selection criteria

Any studies in any habitat that examined the impact on abundance of any management intervention used to control or eradicate any subspecies, variety or hybrid of Japanese knotweed were included. Appropriate spatial or temporal controls were a prerequisite for studies to be included in quantitative analysis. Studies of biological control were not included as no data are yet available on effectiveness.

Data collection and analysis

The inclusion criteria were met by 74 articles, and these included information for Japanese knotweed and the hybrids Bohemian knotweed (*F. x bohemica*) and back-crossed *F. japonica* var. 'Crimson Beauty'. Multivariate synthesis was used to identify broad patterns in the effectiveness of all management interventions, using data extracted from 64 of the included articles only. Data suitable for meta-analyses were extractable from only 11 articles. Meta-analyses were used to examine the following six management techniques only (due to lack of suitable data on any other techniques): the herbicides glyphosate and imazapyr used alone and in combination, cutting applied alone, cutting followed by filling the stem with glyphosate herbicide, and cutting followed by spraying regrowth with glyphosate.

Main results

All six interventions investigated by meta-analysis produced statistically significant decreases in knotweed abundance in the short-term, except for cutting used alone. However, the ecological significance of the impacts of these treatments is uncertain, and there is no robust evidence available regarding their long-term effectiveness. Uncertainty is exacerbated by the small number of individual effect sizes, the limitations of the pooled studies (particularly confounded baselines and short timescales), and the high heterogeneity among included studies. The meta-analyses demonstrate that existing available evidence is insufficient to derive generic evidence-based management guidance for these particular techniques. These conclusions are supported by multivariate analysis of lower quality data from a wider range of sources. Variation in effectiveness was evident both within and between treatments, but this variation could not be linked to any ecological or intervention-related variables.

Timing of control influences the effectiveness of glyphosate application, with application later in the year appearing to have a more significant effect on knotweed abundance. However, the effect is no longer significant when considered alongside the duration of control. This relationship should be treated cautiously, as it could be confounded by one of the many variables that differed between the included studies.

No conclusive evidence was found for differences in effectiveness of management techniques due to taxonomic variation.

Conclusions

Available evidence suggests that applications of the following six control methodologies will not eradicate Japanese or hybrid knotweed in the short-term: the herbicides glyphosate and imazapyr used alone and in combination, cutting applied alone, cutting followed by filling the stem with glyphosate herbicide, and cutting followed by spraying regrowth with glyphosate. The review highlights a lack of readily-available, long-term, robust, controlled experiments assessing the effects of the full range of management techniques used against Japanese and hybrid knotweed. As such, it emphasises important deficiencies within the current body of evidence. The authors of this review are aware of control methods in use other than the six methods analysed in this review. However, as some monitoring results are not made readily available, the effectiveness of the full range of control and eradication methods currently implemented cannot be tested. Readers must therefore put the evidence presented here into a broader context of poor data accessibility.

This review recommends further research into methods used to control and eradicate Japanese knotweed. This research should focus on long-term collection of monitoring data, adequate replication, and investigation of the impacts of treatments on rhizomes. A large, well-replicated experiment or monitoring programme examined over a long time period could be used to test a range of different factors that may influence Japanese knotweed control and eradication. It is recommended that collaboration between stakeholder groups across and between countries be used to achieve a multi-site aspect to this research. Considering the substantial amount of money that is already invested in knotweed control, it would be worthwhile to provide funding for developing more effective ways of managing the problem under different circumstances.

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10. APPENDICES

1. BACKGROUND

Japanese knotweed (*Fallopia japonica*) is a perennial plant reported to be introduced into Europe from Japan in the early to mid-1800s (Beerling *et al.* 1994; Child and Wade, 2000). Originally used as an ornamental, stabilisation plant or cattle fodder, escapes were reported from the mid 19th century, with naturalisation occurring in many places by the late 19th century (Child and Wade, 2000; Bond and Turner, 2006). Due to the subsequent spread of this invasive weed, *F. japonica* is now established alongside railways, canals, rivers and streams, roadsides, and areas of human disturbance such as waste tips. It is widespread in the British Isles and many European countries, and has also become a problem in the USA (becoming naturalised by the late 1800s), Canada, Australia, and New Zealand (Beerling *et al.*, 1994; Child and Wade, 2000; Australian Weeds CRC, 2005). The species has subsequently been described as one of IUCN's top 100 invaders (Lowe *et al.*, 2000). Confusion has arisen over the taxonomy of this species, as it is often referred to by several different specific names, the three most common being *Fallopia japonica*, *Polygonum cuspidatum* and *Reynoutria japonica* (Beerling *et al.*, 1994). Throughout this document, Japanese knotweed will be referred to as *F. japonica*, as described by Stace (1997).

Spread outside Japan is mainly by vegetative means via rhizomes and plant pieces, as most individuals are male-sterile and from a single clone (Bailey, 1994; Hollingsworth and Bailey, 2000; Mandak *et al.,* 2005). However, recent studies have shown that wild seed-set in the plant may be more common than previously realised, at least in the USA (Forman and Kesseli, 2003). Within its native range, reproduction is assisted by wind- and water-dispersed seeds. Successful invasion outside Japan has been facilitated mainly by the deposition of plant material or cartage of soil containing plant fragments; therefore, it can be transported great distances and released accidentally in a relatively easy manner (Child *et al.*, 2001). However, *F. japonica* hybridises with *F. sachalinensis* (Sakhalin or Giant knotweed), the hybrid *F. x bohemica* (also known as *Reynoutria x vivax* or Bohemian knotweed) producing viable seed (Bimova *et al.*, 2001). There is some indication that this hybrid is more invasive than its parents, that it is more difficult to control, and has a higher regeneration rate (Bimova *et al.,* 2001, 2003; Pysek *et al.,* 2003; Mandak *et al.,* 2004). Hybridisation with *F. baldschuanica* (Russian Vine) to produce infertile *F. x conollyana* has also occurred (Bailey, 2001). Both species are widespread in Europe, and *F. x bohemica* is also widespread in the USA (known as *Polygonum x bohemicum*; Zika and Jacobson, 2003) and has been found in Australia (Child and Wade, 2000). Several species varieties also exist, with the main invasive variety being *F. japonica* var. *japonica* (Beerling *et al.*, 1994; Child and Wade, 2000). Other varieties include *F. japonica* var. *compacta*, var. 'Crimson Beauty' and var. 'Variegated'/'Variegata', which are often available as horticultural plants (Beerling *et al.*, 1994; Forman and Kesseli, 2003).

Japanese knotweed can grow up to 3m high (Beerling *et al.*, 1994) and forms tall thickets that exclude all other vegetation (Child and Wade, 2000; Bond and Turner, 2006). A dense leaf canopy is created, shading the area below, and when the leaves are shed in autumn, they and the dead stems decompose slowly, forming thick mulch that restricts the growth and germination of other plants (Beerling *et al.*, 1994; Child and Wade, 2000). Native plants therefore cannot compete with this invasive, and local plant biodiversity is reduced (Seiger, 1991; Child and Wade, 2000; Sewak, 2005).

Various methods for control and eradication of Japanese knotweed have been used. Mechanical methods such as grazing, cutting, mowing, pulling and digging have been used to control outbreaks (Seiger, 1991; Child and Wade, 2000; Soll, 2004; Bond and Turner, 2006). Herbicides are frequently used to control or eradicate the weed over several years, and several herbicides (selective and non-selective) and application methods (e.g. stem injection) are in use (Seiger, 1991; Child and Wade, 2000; Soll, 2004). Large-scale excavation is usually considered as the only method of rapid eradication (Environment Agency, 2006; Japanese Knotweed Alliance website). Geosynthetic textiles and thick polythene sheeting have been utilised to reduce the spread of Japanese knotweed. These can be used to encase excavated material or cover infestations and then buried, or they can be placed into the ground beside infestations to act as a vertical barrier (Environment Agency, 2006; REC Ltd. website; Wreford Ltd. website). Combinations of the various control methods are also used. In addition, investigations are being conducted into possible biological controls for Japanese knotweed, but these are still in the early stages of research (Japanese Knotweed Alliance website).

Defra (2003) estimated it would cost £1.56 billion to eradicate Japanese knotweed across all infestation in Britain, with £52 million of that estimate related to removal of the weed from riparian areas. Fasham and Trumper (2001) stated that £160,000 had been spent on controlling Japanese knotweed in the Swansea area since 1992, with estimated costs of full control in the area at nearly £8 million. The threat of this plant to native flora has been recognised and there is now UK legislation surrounding its handling and planting (Child and Wade, 2000). There is also a growing awareness of the impacts of Japanese knotweed in others areas of the world, and as such it is becoming more recognised by legislation (for examples see Child and Wade, 2000). It is therefore desirable to review the effectiveness of measures taken to control or eradicate Japanese knotweed.

Using systematic review methodology, the interventions used to control or eradicate Japanese knotweed were critically appraised. The review considered the best available evidence of the effectiveness of different control and eradication methods in different situations. The review limited bias through the use of comprehensive literature searching (both published and unpublished), specific inclusion criteria, and formal standardised assessment of the quality and reliability of the studies retrieved. Subsequent data synthesis of both qualitative and quantitative information summarised all available evidence. This was used to critically appraise the knowledge base of current knotweed management guidance, and to identify needs-led research as a priority for future funding.

2. OBJECTIVES

2.1 Primary objective

To systematically collate and synthesise published and unpublished evidence in order to address the question:

> "Are Japanese knotweed (*Fallopia japonica*) control and eradication interventions effective?"

2.2 Secondary objective

To investigate whether the effectiveness of control and eradication treatments for Japanese knotweed is influenced by the following factors:

1. Environmental and geographical factors: habitat type, temperature, rainfall, soil moisture, soil type, ground slope, shading, latitude/longitude, and altitude.
2. Operational level variables: age of stand, height of stand, density of knotweed, size of controlled area, previous control, duration/effort/timing of control, chemical aspects of control methods (e.g. herbicide type, herbicide application method, concentration of herbicide, number of herbicide applications), mechanical aspects of control methods (e.g. cutting and digging/excavation techniques), and type of grazer.
3. Hybridisation (i.e. *F. x bohemica*, *F. x conollyana*) and species variety (i.e. *Fallopia japonica* var. *japonica, F. japonica* var. *compacta*, *F. japonica* var. 'Crimson Beauty', *F. japonica* var. 'Variegated'/'Variegata').

3. METHODS

3.1 Question formulation

The subject of Japanese knotweed control was proposed by the Environment Agency (UK) as one of a list of invasive species control issues. The question was developed in conjunction with United Utilities PLC, a UK water company. United Utilities PLC identified the need to evaluate control and eradication methods used for Japanese knotweed under a variety of circumstances and time periods, particularly within the contexts listed below:

1. In-situ eradication within 1-3 months
2. In-situ eradication over 12 months
3. In-situ eradication 12 months+
4. Excavate and move infestation to a 'safe area' for long term (2-3 years) treatment
5. In-situ treatment within 3-12 months adjacent to a watercourse
6. Creation of barriers to adjacent infestations on 3rd party land
7. Treatment of infestations whilst protecting adjacent more favourable vegetation species

The draft review protocol was made available to a wide range of UK stakeholder groups (including statutory and non-statutory organisations) that could supply guidance on the direction of the review, or could potentially provide information for use in the review. Specific groups contacted were: Cornwall (Japanese) Knotweed

Forum, Devon Knotweed Forum, Tweed Forum, Japanese Knotweed Alliance (CABI Bioscience), and the Japanese Knotweed Mailing List (subscribers to which belong to research and contractor organisations of both UK and non-UK origins). A number of contacts were also made with people identified to be 'experts' in this area or who had published articles on Japanese knotweed, especially those who were regularly quoted in the preliminary literature that was obtained. Responses from these contacts further modified the interventions listed in the review protocol.

3.2 Search strategy

3.2.1 General methodology

A wide range of general and specialist data sources were searched for relevant information. Searching was conducted between December 2005 and May 2006. However, feedback and direct contacts continued to provide data until the review was finalised in January 2007. All searching was performed by a single reviewer (TJK) using the search terms and resources detailed below. The searching functionality of each organisational and specialist source, and other electronic resources and catalogues varied greatly. Therefore, different combinations of the pre-defined search terms were used or appropriate links within the websites were followed. All references retrieved in each of these engines were examined for relevant information. Details of the full search strategy can be found in Table 1 of Appendix 1.

Non-English language searches were not conducted. However, the search identified studies on a global scale, including a number of non-English language articles. Potential non-English language literature and data sources were also identified via contact with subject experts.

3.2.2 General sources

Electronic databases

Relevant articles were identified through electronic database searching completed using the following nine databases: Agricola, CAB Abstracts, Digital Dissertations Online, Index to Theses Online, ISI Web of Knowledge (including ISI Web of Science and ISI Proceedings searches), JSTOR, Science Direct, Scirus (all journal sources), and Scopus. All references retrieved via these searches were examined for relevance. The following search terms were used for all electronic databases (* indicates the use of a wildcard):

1. *Fallopia* AND *japonica*
2. *Polygonum* AND *cuspidatum*
3. *Reynoutria* AND *japonica*
4. Japanese AND knotweed
5. *Fallopia* AND *japonica* AND control*
6. *Polygonum* AND *cuspidatum* AND control*
7. *Reynoutria* AND *japonica* AND control*
8. Japanese AND knotweed AND control*

Internet resources

Web-engine searches were completed using the following four engines: AllTheWeb, Dogpile, Google Scholar, and Scirus (all web sources). The above set of search terms were modified for web searching due to the large, and often irrelevant, numbers of references retrieved by web-engines, and differences in individual engine functionality. Search terms used were based on the series:

1. "Fallopia japonica" AND (control OR controlled OR controlling)
2. "Polygonum cuspidatum" AND (control OR controlled OR controlling)
3. "Reynoutria japonica" AND (control OR controlled OR controlling)
4. "Japanese knotweed" AND (control OR controlled OR controlling)

For Scirus web source searching, the term '(control OR controlled OR controlling)' was replaced by 'control*' due to wildcard ability. The first 50 articles from each search term in each engine were examined for relevant information.

Other electronic resources and catalogues

Further references were located through the following nine computerised and internet-based catalogues and other resources: Blackwell Synergy, ConservationEvidence.com, Copac, Directory of Open Access Journals, English Nature's computerised library catalogue "Wildlink", Elsevier, European Nature Information System database V2 (EUNIS), iSpecies, and SpringerLink.

Other sources

Bibliographies of articles accepted into the review, and from traditional literature reviews, were inspected for relevant secondary articles not retrieved via other methods. Relevant literature lists were also inspected for further references. Authors, recognised experts and practitioners in the field of Japanese knotweed control were contacted for further recommendations, and for provision of any unpublished material or missing data that may be relevant.

Although identified within the protocol as an action, questionnaires were not circulated to practitioners in order to collate experience for use in the review due to available resources. However, contact with practitioners was made through other means.

3.2.3 Specialist sources

The following statutory and non-statutory organisation websites were searched for relevant information:

UK and Ireland: ADAS, Biotechnology and Biological Sciences Research Council (BBSRC), British Waterways, Countryside Council for Wales (CCW), Centre for Ecology & Hydrology (CEH), Cornwall County Council, Cornwall (Japanese) Knotweed Forum, Defence Science and Technology Laboratory (DSTL), Dept. for Environment Food and Rural Affairs (Defra), Dept. Agriculture and Rural Development (DARD), Devon Knotweed Forum, English Nature (EN), Environment Agency (EA), Environment Planning & Countryside Wales, Forestry Commission GB, Forest Research, Government of Ireland, HDRA Organic Weeds, Irish Environmental Protection Agency (EPA), Japanese Knotweed Alliance, Joint Nature Conservation Committee (JNCC), National Assembly for Wales, Natural Environment Research Council (NERC), Network Rail, Northern Ireland Dept. of Environment, Northern Ireland Environment and Heritage Service (EHS), Northern Ireland Executive, Royal Society for the Protection of Birds (RSPB), Royal Horticultural Society (RHS), Scottish Executive Environment and Rural Affairs Department (SEERAD), Scottish Environmental Protection Agency (SEPA), Scottish

Natural Heritage (SNH), Tweed Forum Invasives Project, The Macaulay Institute, The National Trust, UK Biodiversity Action Plan, Welsh Assembly Government.
USA: Clark County Washington, Greene County Soil & Water Conservation District, JK Injection Tools, Pennsylvania State University, Pennsylvania State University – Integrated Pest Management, Pennsylvania State University – Roadside Vegetation Management Research, Pennsylvania State University – Weed Management, USDA Forest Services, Washington State Dept. of Agriculture, Washington State Noxious Weed Control Board.
Europe: Europa, European Environment Agency.
International: World Wide Fund for Nature (WWF).

Specialist searching was completed on the following invasive species websites: Japanese Knotweed Mailing List Archives, Introduced Species in the British Isles, Invasive Alien Plants (EMAPi conference information), Invasive & Exotic Species, Invasive Non-Native Species in the UK, Ecology & Management of Invasive Plants, National Invasive Species Information Center (NISIC), Invasive Weeds UK, ISSG's Global Invasive Species Database, National Institute of Invasive Species Science, NBII Invasive Species Information Node, NISBase: Nonindigenous Species Database Network, Noxious Weeds in the US and Canada, and Sea Grant Nonindigenous Species Site (SGNIS).

3.2.4 Literature scoping for other names and hybrid species

As Japanese knotweed is known under a very wide variety of Latin species and common names, it was decided that only the most widely accepted names should be searched in the review. However, the variety of other names were scoped for relevance. A list of search terms and databases used is included in Appendix 2. The names of Japanese knotweed hybrids were also selected for scoping, as there was interest from contacts on potential differences in the effectiveness of control and eradication methods. A list of search terms and databases used is included in Appendix 3. The combined scoping searches located 80 references, 32 of which had not been retrieved previously. However, none of these proved relevant; therefore further use of alternative nomenclature was considered unnecessary.

3.3 Study inclusion criteria

All articles identified from the search strategy were examined at title and abstract level by a single reviewer (TJK), using pre-defined inclusion and exclusion criteria. Articles were accepted as relevant to the next stage of the review process (full text assessment) if they appeared to contain information relevant to the review question, or if insufficient information was available to determine that an article was not relevant. A second reviewer (GBS) examined a random subset of 25% of the article reference list derived from the electronic database and Copac searches only (n=164) to assess repeatability of the relevance assessment. Kappa analysis was performed, with an agreement rating of 'substantial' (Cohen's Kappa test: K=0.68) indicating that study inclusion was repeatable. Acceptance into the review after the full text assessment stage was conducted by a single reviewer (TJK), with reference to a second (GBS) in cases of uncertainty.

The review-specific criteria that articles had to meet for inclusion into the final stage of the systematic review were:

1. *Subject*: Japanese knotweed, of any subspecies or variety or hybrids, in any habitat regardless of geographical location.
2. *Intervention*: All techniques implemented to control or eradicate Japanese knotweed were included, e.g. herbicides, cutting, grazing, barriers, and combination techniques.
3. *Outcome*: The primary outcome was change in the abundance of treated Japanese knotweed population at a local scale. However, articles were not rejected on the basis of outcome. Articles that included only outcomes that referred to changes in the population as a result of the control method, the cost effectiveness of different control and eradication methods, or the impact on species other than Japanese knotweed, were catalogued and not included in quantitative synthesis.
4. *Type of study*: All studies investigating the control or eradication of Japanese knotweed were included if they presented primary data about a relevant subject and intervention. Only studies with appropriate spatial or temporal controls or comparators and with replication (including pseudoreplication) were included in the meta-analyses.

Articles were not accepted into the final review if they belonged to the following categories:

1. Biological control studies (these were obtained for full text assessment but were not included in the final review as no data are yet available on effectiveness.
2. Studies where it could not be clearly determined whether the results were referring to Japanese knotweed (or hybrids) on its own or not, i.e. studies that reported control or eradication of Giant and/or Bohemian knotweed as well as Japanese knotweed without clearly distinguishing between the results for each species.
3. Studies that investigated shade or nutrient control as the only intervention.
4. Articles that duplicated results presented in other articles that provided more information.

3.4 Study quality assessment

Articles viewed at full text were assessed for inclusion into different categories of information quality. Studies that presented information on the control and eradication of Japanese knotweed, regardless of quality, were included in a multivariate synthesis. This was used to examine broad patterns in the effectiveness of different methods. Methodological details were recorded on a data extraction form, and included a critical appraisal of study design (i.e. randomised controlled trial, controlled trial, site comparison, time series, or ‘snapshot’ where data related to a single time period or timescale could not be determined), number of replicates, use of an objective abundance parameter, and duration of control effort.

Meta-analyses were used to combine different (but similar) studies to increase statistical power and to quantify, and where possible, explore variation between studies. Study quality assessment consisted of recording study design (as described above), replication, duration, and parameter of abundance. The biases resulting from study design were considered, and an explicit statement regarding the primary biases was included along with information detailing the data extraction. Study quality assessment was undertaken by one reviewer (TJK) with reference to a second (GBS) in cases of uncertainty.

3.5 Data extraction

3.5.1 Meta-analysis

Details of data extraction were recorded for all studies included in the meta-analyses to increase the transparency of the review process. The following *a priori* data extraction rules were established to minimise bias and increase repeatability:

- Where Before-After-Control-Intervention (BACI) data were presented, change over time in treatment and control were extracted preferentially, along with the variance of change over time. Where it was not possible to derive this variance, data were treated as a site comparison with variance derived from repeated samples in space at the end of experiment. Before and after data were extracted where a time series from a single site was available.
- Multiple effect sizes could only be extracted from a single source if they were derived from independent comparators. Where there was doubt about independence, data were pooled and extracted as one effect size. In some instances, different treatments were compared to the same controls, i.e. different dosages or numbers of applications of the same herbicide. For these studies, data were extracted based on the treatment most similar to others in each analysis for herbicide dosages, or for the longest time range and a single application where possible.
- Data of the longest time range were extracted in order to increase predictive power and maintain independence where there was a choice of time ranges.
- Where there was a choice of outcome measures, objective parameters of abundance were extracted preferentially (e.g. stem density rather than percentage cover assessed by eye), and stem density/counts were extracted over other objective outcomes.
- Variance measures were preferentially extracted at the site level with variance derived from within-site replication or pseudoreplication. However, variance was derived across sites where no other data were available, in preference to total exclusion from the meta-analysis. Where variance data were not available, the study was not included in the meta-analysis. Variances were only imputed in instances where variance was zero, in which case a dummy value of 0.001 was used.

For studies where information required for meta-analysis was missing or inferred, authors were contacted in order to increase the number of studies included in the meta-analyses. If no further information could be obtained, the studies were included in the multivariate synthesis only.

Data were extracted for meta-analysis by a single reviewer (TJK) with assistance and quality control provided by a second reviewer (GBS). A formal assessment of data hygiene and extraction was not performed; however, a study-by-study check of extraction technique was conducted.

3.5.2 Multivariate synthesis

Information regarding the intervention and related variables, data quality, biogeographical context, and outcome of all relevant studies was extracted for multivariate analysis.

Each data point from each intervention was rated for effectiveness using *a priori* rules to classify effectiveness as percentage control:

• very effective	>-75%
• effective	-50 to -75%
• neutral	-25 to -50%
• ineffective	0 to -25%
• very ineffective	>0%

Herbicide types were coded by those studies using a single active ingredient first (e.g. glyphosate), then a combination of active ingredients (e.g. imazapyr + glyphosate), and finally use of multiple herbicides over time (e.g. glyphosate year 1, imazapyr year 2). The same approach was adopted for mechanical techniques.

Climate maps (http://www.fao.org/sd/eidirect/climate/eisp0002.htm) were used to estimate annual temperature and rainfall values for sites, while also acting as a proxy for rarely reported latitudinal and longitudinal data. Location was estimated to the nearest state or county where possible.

Some variables of interest were excluded from analysis due to lack of standardised reporting. These were: habitat type, former land use, soil moisture, soil type, ground slope, shading, longitude/latitude, altitude, age of stand, height of stand, density of knotweed, size of controlled area, previous control, concentration of herbicide, and type of grazer).

Where data were missing, averages (for duration of control, effort per year, time between combination techniques, and time between multiple applications) or modes (for timing of control and number of applications) of data from other included studies were substituted. Logical assumption of missing data was also used for some variables (herbicide application method, species, study design, replication, and objectivity of abundance parameter).

The same data extraction rules used for meta-analytical data were applied, although data without controls and variance measures were included in this synthesis. Where presented, percentage control values were used from studies or were calculated, either against an untreated control or pre-treatment value, or against the least effective treatment in the study. If information was not presented, then an assumption was made regarding effectiveness outcomes based on other information presented in the study. The authors' own assessments of effectiveness were also used where no other information was presented, or when non-numerical assessments of effectiveness represented the longest time range.

The repeatability of scoring effectiveness outcomes was assessed using 10 articles (59 data points) selected to represent the range of data quality. The proportion of agreement between two independent reviewers was 44%.

3.6 Data synthesis

3.6.1 Meta-analysis

Meta-analysis was used to combine studies with comparators and variance measures (Cooper and Hedges, 1994; Scheiner and Gurevitch, 2001; Deeks *et al.*, 2001). Cohen's D effect sizes (Deeks *et al.*, 2001) were derived from the treatment and control (or pre- and post-treatment) mean abundance data, standard deviations and sample sizes extracted from the primary studies. Data were pooled and combined across studies using DerSimonian and Laird random effects meta-analysis based on standardised mean difference (SMD; DerSimonian & Laird, 1986; Cooper & Hedges, 1994) using Stata version 8.2 (Stata Corporation, USA, 2003). The random effects model anticipates that the true effect size differs among studies, and is appropriate for ecological questions where the true effect is likely to vary between studies as a result of ecological variation between sites (Gurevitch and Hedges, 1999). The standardised mean difference method expresses the size of the treatment effect in each study relative to the variability observed in that study (Deeks *et al.* 2001), allowing combination of the different knotweed abundance parameters reported in the primary studies.

Sufficient data were only available for analysis of the following interventions: the herbicides glyphosate and imazapyr used alone and in combination, cutting applied alone, cutting followed by filling the stem with glyphosate herbicide, and cutting followed by spraying regrowth with glyphosate. The impact of these interventions was examined by inspection of Forrest plots of the estimated treatment effects from the studies, along with their 95% confidence intervals. Formal tests of homogeneity undertaken prior to each meta-analysis (Thompson and Sharp, 1999) were used to assess the statistical significance of heterogeneity between studies.

Further analyses could only be performed on the glyphosate data, as sample sizes for the other analyses were too small. Univariate and multivariate random effects SMD meta-regressions were used to explore the impacts of duration of control, timing of application, and the two factors combined using the Stata version 8.2 program Metareg (Sharp, 1998). Other predefined variables for extraction were insufficiently reported for robust analysis, although subgroup analyses were performed to assess the impact of including hybrid knotweed data on the effectiveness of glyphosate used alone. Publication bias was investigated by examination of Funnel plot asymmetry (plot of effect size estimates against the inverse of their standard errors) (Egger *et al.*, 1997). This was performed using Stats Direct version 2.5.6.

3.6.2 Multivariate synthesis

We examined the general structure of Japanese and hybrid knotweed data (including data without comparators) using Detrended Correspondence Analysis (DCA) (Hill, 1974) in PC-ORD version 4.0. No transformation or down-weighting was undertaken to avoid introducing *post hoc* bias. Gradient lengths of the ordination axes (of >3) suggested that Canonical Correspondence Analysis (CCA) was the appropriate means of analysing the relationships between the effectiveness of knotweed management and ecological, methodological, and data quality variables (ter Braak & Smilauer, 2002). Two-Way Indicator Species Analysis (TWINSPAN) (Hill, 1979) was used to classify samples as a complementary approach to the ordinations.

4. RESULTS

4.1 Review statistics

Details of the number of articles included at each review stage are provided in Table 1. A total of 304 articles were selected for full text viewing from all searching sources (74 from electronic databases + Copac, 230 from all other sources). Of these, 38 were not obtained due to trade off between potential value and the time and resource constraints of the review (list available on request). Several articles relating to biological control were also not located, as this intervention is not currently practiced and it was not feasible to put resources into locating these. Therefore, only 266 articles were assessed at the full text viewing stage. Of these, 96 were assessed as being guidance documents only (including traditional reviews) (Appendix 4) and a further 96 were excluded from the review (list available on request). Seventy-four articles were accepted into the review as containing information related to actual control or eradication of Japanese knotweed. The full search results can be found in Table 2 of Appendix 1.

Table 1. Number of articles included at each of the systematic review filtering stages.

Systematic review stage	**No. of articles**
References identified from electronic database + Copac searching after removal of duplicates	656
References remaining from electronic database + Copac search after relevance assessment of articles at title & abstract stage.	74
References identified from searching via other sources	230
Articles from all sources judged relevant after full text viewing	74
Relevant articles excluded from further analysis (articles contained secondary outcomes or unusable information)	9
Relevant articles providing data used in multivariate synthesis	64
Relevant articles providing data used in meta-analyses (also used in multivariate synthesis)	11

4.2 Description of studies

Examples of management of both Japanese knotweed (*F. japonica*) and the hybrid Bohemian knotweed (*F. x bohemica*) were found. One study also included data on hybrid back-crosses of Japanese knotweed with the horticultural variety *F. japonica* var. 'Crimson Beauty'. Information was not located for other varieties or hybrids. Of the 74 articles accepted into the review, only 11 studies presented enough quantitative data (with comparator and variance measures) to enable meta-analyses to be performed. These studies included investigations of the effects of the herbicides glyphosate and imazapyr, alone and in combination, cutting applied alone, cutting followed by filling the stem with glyphosate herbicide, and cutting followed by spraying regrowth with glyphosate. There was considerable variation in the key characteristics of the quantitative studies, particularly in the duration and timing of experiments, outcome measures used for cutting trials, and experimental design (Tables 2 to 7). A total of 38 independent effect sizes were extracted and used in the meta-analyses. The data extraction tables are included as Appendix 5. Due to limited reporting, a decision was made (*a priori* to analysis) to extract only intervention-related variables (duration of control, timing of application, number of applications, and herbicide dosage rate) for inclusion in meta-regressions. Data for timing of application could not be extracted for the Gozart (2006) glyphosate data as aggregation bias would have occurred by using the average of the two months in which the treatment was applied.

The 63 remaining articles did not contain meta-analysable data, and included qualitative or anecdotal studies and quantitative studies that did not provide comparators or measures of variance. Eight of these studies were excluded from further analysis because they addressed only the secondary question of costs of management techniques (five), or the herbicide they used was not specified (three). A further study was excluded as it investigated concrete revetment blocks, an atypical intervention that was difficult to extract for analysis. A reference list of these excluded articles is provided in Appendix 6. The remaining 54 articles were combined with data included in the meta-analyses, and 343 data points were extracted for the multivariate synthesis. A full reference list of articles from which data were extracted is included as Appendix 7, and an abridged version of the DCA data extraction table is included as Appendix 8.

Table 2. Characteristics of studies included in meta-analysis of glyphosate effectiveness (RCT=Randomised controlled trial, CT=Controlled trial, SC=Site comparison, TS=Time series).

		Outcome		Methodological						Ecological
Study	**Intervention**	**Abundance measure**	**Mean difference**	**Design**	**Replication**	**Duration (months)**	**Timing of application**	**Number of applications**	**Dosage**	**Species**
Figueroa 1989	Glyphosate spray - paved area	Stem density (shoots.m^{-2})	-6.50	CT extracted as SC	2	11	June	1	3.4kg ai/ha	*Fallopia japonica*
	Glyphosate spray - unpaved area		-10.00							
Scott & Marrs 1988	Glyphosate spray	Stem density (shoots.m^{-2})	9.00	RCT extracted as SC	3	15	May	1	2.2kg/ ha ai	*Fallopia japonica*
Stingelin Keefer 2002	Glyphosate spray – site1	Number of stems	34.00	RCT extracted as SC	3	14	May	1	4kg ai/ha	Back-crossed *F. japonica* var. *'Crimson Beauty'*
	Glyphosate spray – site2		-23.34							*Fallopia x bohemica*
Miller 2005	Glyphosate injection – Beacon Rock	Number of stems	-24.25	TS extracted as SC	4	11	July	1	5mL per stem	*Fallopia x bohemica*
	Glyphosate injection – Upper Clark		-24.63							*Fallopia japonica*
	Glyphosate injection - Skamania		-37.13							*Fallopia japonica*

Gozart 2006	Glyphosate injection	Number of stems	-40.00	CT extracted as SC	2	23.5	Jul/Sep	1	5mL per stem	*Fallopia x bohemica*
	Glyphosate injection + spray		-119.5		2	23.75	Jul/Aug	2	5mL per stem, spray unknown	
Burgess 2005a	Glyphosate injection	Number of stems	-9.00	TS extracted as SC	2	1.5	June	1	4mL per stem	*Fallopia x bohemica*
	Glyphosate injection		-49.71		7				6mL per stem	*Fallopia x bohemica*
Burgess 2005b	Glyphosate injection	Number of stems	-10.00	TS extracted as SC	3	2	July	1	4mL per stem	*Fallopia japonica*
	Glyphosate injection		-12.25		4				5mL per stem	*Fallopia japonica*

Table 3. Characteristics of studies included in meta-analysis of effectiveness of cutting (RCT=Randomised controlled trial, CT=Controlled trial, SC=Site comparison, TS=Time series).

		Outcome		**Methodological**					**Ecological**	
Study	**Intervention**	**Abundance measure**	**Mean difference**	**Design**	**Replication**	**Duration (months)**	**Timing of application**	**Number of applications**	**Location**	**Species**
Beerling & Palmer 1994	Cutting	Increase in radius (cm)	61.19	CT extracted as SC	3 treatment, 6 control	24	June	1	In-situ	*Fallopia japonica*
Bimova *et al.* 2001	Cutting	Stem density (shoots.m^{-2})	-3.00	RCT extracted as SC	4	17	May	2	In-situ	*Fallopia japonica*
			3.00							*Fallopia x bohemica*
Scott & Marrs 1988	Cutting	Stem density (shoots.m^{-2})	-16.00	RCT extracted as SC	3	15	May	1	In-situ	*Fallopia japonica*

Seiger & Merchant 1997	Cutting	Below ground biomass (g)	-11.23	RCT extracted as SC	90 treatment, 30 control	Approx. 5.5	Pooled June/ July/August	1	Ex-situ	*Fallopia japonica*

Table 4. Characteristics of studies included in meta-analysis of effectiveness of cutting followed by spraying regrowth with glyphosate (RCT=Randomised controlled trial, CT=Controlled trial, SC=Site comparison, TS=Time series).

		Outcome		**Methodological**						**Ecological**
Study	**Intervention**	**Abundance measure**	**Mean difference**	**Design**	**Replication**	**Duration (months)**	**Timing of application**	**Dosage**	**Number of applications**	**Species**
Stingelin Keefer 2002	Cut & glyphosate spray – site1	Number of stems	-7.34	RCT extracted as SC	3	15	May cut, June spray	4kg/ha ai	1	Back-crossed *F. japonica* var. *'Crimson Beauty'*
	Cut & glyphosate spray – site2		-12.01							*Fallopia x bohemica*
Bimova *et al.* 2001	Cut & glyphosate spray	Stem density (shoots.m^{-2})	-47.67	RCT extracted as SC	4	17	May cut, July spray	50mL per 100m^2	2	*Fallopia japonica*
			5.33							*Fallopia x bohemica*

Table 5. Characteristics of studies included in meta-analysis of effectiveness of cutting and filling stems with glyphosate (RCT=Randomised controlled trial, CT=Controlled trial, SC=Site comparison, TS=Time series).

		Outcome		**Methodological**						**Ecological**
Study	**Intervention**	**Abundance measure**	**Mean difference**	**Design**	**Replication**	**Duration (months)**	**Timing of application**	**Dosage**	**Number of applications**	**Species**
Joy 2002	Cut & fill glyphosate - Covington	% cover	-16.00	TS extracted as SC	5	32-33	August - September	10x recommended dose for spraying	3	*Fallopia japonica*
	Cut & fill glyphosate - Cot		-75.72		5					
	Cut & fill glyphosate - Kenidjack		-71.00		3					
Burgess 2005b	Cut & fill glyphosate	Number of stems	-1.20	TS extracted as SC	5	2	July	1mL per stem	1	*Fallopia japonica*

Table 6. Characteristics of studies included in meta-analysis of imazapyr effectiveness (RCT=Randomised controlled trial, CT=Controlled trial, SC=Site comparison, TS=Time series).

		Outcome		**Methodological**						**Ecological**
Study	**Intervention**	**Abundance measure**	**Mean difference**	**Design**	**Replication**	**Duration (months)**	**Timing of application**	**Dosage**	**Number of applications**	**Species**
Stingelin Keefer 2002	Imazapyr spray - site1	Number of stems	-50.00	RCT extracted as SC	3	14	May	0.5kg/ha ai	1	Back-crossed *F. japonica* var. *'Crimson Beauty'*

	Imazapyr spray - site2		-33.34							*Fallopia x bohemica*
Miller 2004	Imazapyr injection -Lower Clark	Number of stems	-31.50	TS extracted as SC	4	11	July	1.5% solution	1	*Fallopia x bohemica*
Figueroa 1989	Imazapyr spray - paved site	Stem density (shoots.m^{-2})	-20.00	CT extracted as SC	2	11	June	0.6kg ai/ha	1	*Fallopia japonica*
	Imazapyr spray - unpaved area		-9.00							

Table 7. Characteristics of studies included in meta-analysis of effectiveness of imazapyr combined with glyphosate (RCT=Randomised controlled trial, CT=Controlled trial, SC=Site comparison, TS=Time series).

		Outcome		Methodological						Ecological
Study	**Intervention**	**Abundance measures**	**Mean difference**	**Design**	**Replication**	**Duration (months)**	**Timing of application**	**Dosage**	**Number of applications**	**Species**
Stingelin Keefer 2002	Imazapyr + glyphosate spray – site1	Number of stems	-51.33	RCT extracted as SC	3	14	May	Imazapyr 0.5 + glyphosate 4kg ai/ha	1	Back-crossed *F. japonica var. 'Crimson Beauty'*
	Imazapyr + glyphosate spray – site2		-30.34							*Fallopia x bohemica*
Gozart 2006	Imazapyr + glyphosate spray	Number of stems	-60.50	CT extracted as SC	4	22.6	Sep	Glyphosate 4.5% + imazapyr 1.5% solution	1	*Fallopia x bohemica*

	Imazapyr + glyphosate spray and/or glyphosate injection		-107.22		9	23		Glyphosate 4.5% + imazapyr 1.5% solution, glyphosate injection 5mL per stem	2	
Miller 2004	Imazapyr + glyphosate injection – Lewis	Stem counts	-51.50	TS extracted as SC	3	11	July	Imazapyr 0.75% + glyphosate 1.5%	1	*Fallopia x bohemica*
	Imazapyr + glyphosate injection – Pacific		-38.25							

4.3 Meta-analysis

4.3.1 Glyphosate alone

Only seven studies (providing 14 effect sizes) present suitable data for meta-analysis of glyphosate herbicide used on its own. Treatment with glyphosate results in a statistically significant decrease in abundance of Japanese knotweed and identified hybrids (Bohemian knotweed or back-crossed 'Crimson Beauty') within 1.5 to 23.75 months (Figure 1; d=-1.9785, z=3.82, 95% CI=-2.99361 to -0.963387, p<0.000). There are five significantly negative individual effect sizes, while no effect sizes are significantly positive. The range in variation in characteristics of the studies results in significant heterogeneity in effect sizes (chi-squared=31.45, df=13, p<0.002). Two possible reasons for this heterogeneity are the timing of control (month) and the duration of the control effort (number of months). The effects of these variables were explored using meta-regression. When each variable is considered in a univariate analysis, timing of control is significant (coef=-1.35828, z=-2.47, p<0.013), but duration of control effort is not (coef=0.0795598, z=1.09, p<0.277). When considered together in a multivariate analysis, neither variable is significant. Funnel plot asymmetry and the Egger test indicate that there is no significant publication bias in the glyphosate data set (Figure 2; Egger test=-2.556716, p<0.143).

Subgroup analyses were performed to investigate the difference in effect of glyphosate on Japanese knotweed and its hybrids (see Table 2). The pooled effect sizes of both analyses remains significantly negative. Although the pooled effect size for Japanese knotweed is more negative than that of the hybrids (Japanese knotweed: d=-2.45316, z=2.85, p<0.004; hybrid knotweed: d=-1.70493, z=2.44, p<0.0015), there is an overlap in confidence intervals between the two subgroups (Japanese knotweed: 95% CI=-4.14069 to -0.765628; hybrid knotweed: 95% CI=-3.07421 to -0.335641), indicating that there is no significant difference in their response to glyphosate.

4.3.2 Other interventions

Data on interventions other than glyphosate alone were limited. Cut and spray regrowth with glyphosate, cutting followed by filling stems with glyphosate, imazapyr alone, and imazapyr combined with glyphosate have significantly negative pooled effect sizes, resulting from decreases in Japanese and Bohemian knotweed abundance over 11 to 32-33 months (Figure 3B, C, D and E; Table 8). Significant reductions in knotweed abundance are not achieved within 30 months by cutting used alone (Figure 3A; Table 8).

The small numbers of studies included in each of these meta-analyses precluded the use of meta-regressions to investigate any reasons for heterogeneity between studies where this was significant (cutting alone, cut and spray regrowth, and cut and fill stems; Table 8). There is considerable variation between effect sizes used in the cutting analysis due to methodological differences, such as outcome measure, replication, number of applications, timescale and species. Two effect sizes are significantly negative, and none are significantly positive. The most negative of these is from an *ex-situ* experiment with high replication that investigated rhizome biomass over approximately 5.5 months, making it very different to other studies included in the analysis.

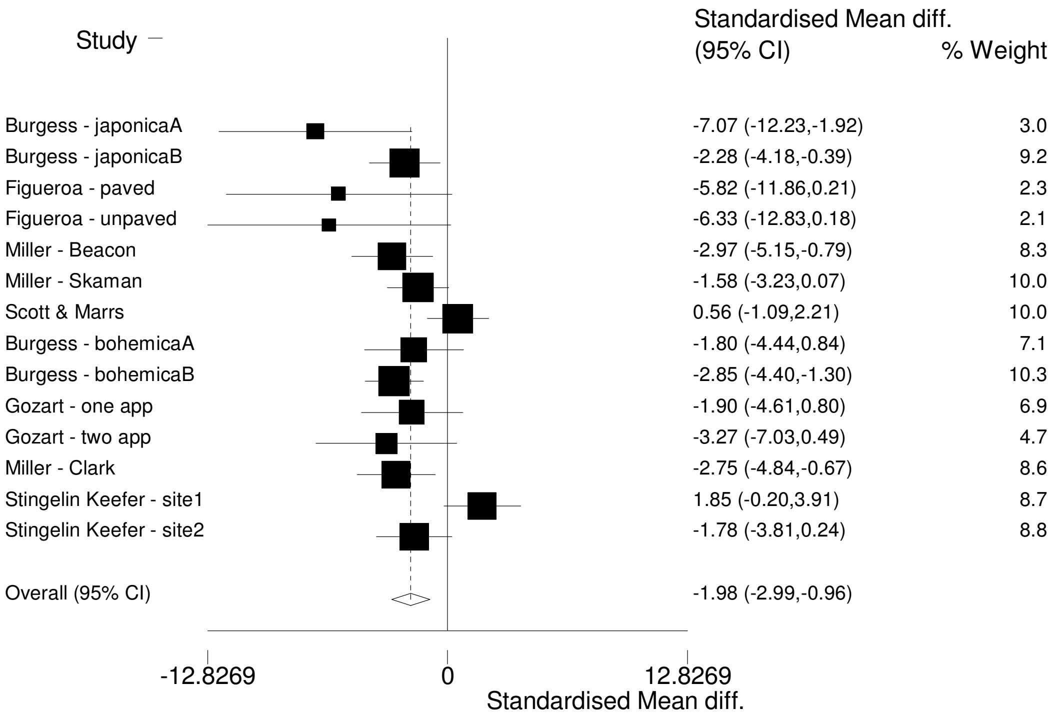

Figure 1: Forrest plot of glyphosate treatment effect sizes (compared against untreated control or pre-treatment measurement). Solid boxes represent the effect size of individual studies; box size is related to sample size. Error bars are 95% confidence intervals. The open diamond is the pooled effect size generated using standardised mean difference random effects meta-analysis. The upper seven effect sizes relate to Japanese knotweed; the lower seven relate to hybrid knotweed.

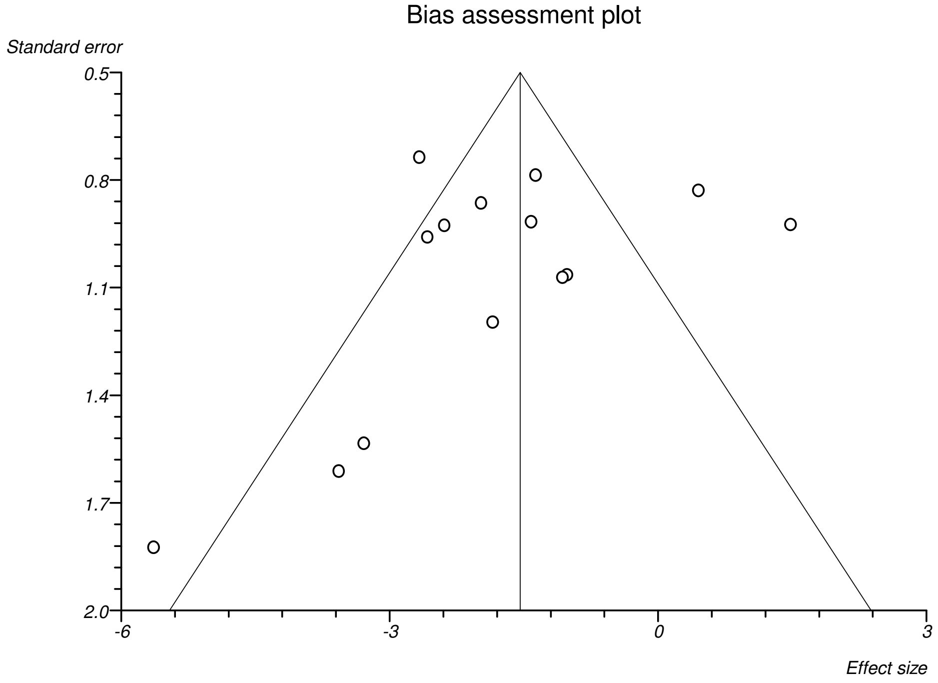

Figure 2. Funnel plot of glyphosate treatment effect size to standard error relationship.

In the cut and spray regrowth with glyphosate analysis, three of the effect sizes are significantly negative and none are significantly positive. The main variation between the two studies is due to species and number of applications. However, there are no clear patterns in variation due to either of these variables.

There is considerable variation between effect sizes used in the cut and fill stems with glyphosate analysis due to methodological differences, such as outcome measure, number of applications, and timescale. Three effect sizes are significantly negative, and none are significantly positive.

Table 8. Meta-analysis results for the effectiveness of interventions other than glyphosate treatment used in managing Japanese or Bohemian knotweed. P-value was significant at 0.05. A significant p-value (0.05) for Q indicates significant heterogeneity between studies included in the meta-analysis.

Intervention	Pooled effect size (d)	95% confidence interval	z	p-value for d	Chi-squared (Q)	Degrees of freedom	p-value for Q
Cutting alone	-0.470527	-1.9738 to 1.03274	0.61	0.540	24.94	4	0.000
Cut & spray glyphosate	-3.205	-6.30983 to -0.100168	2.02	0.043	16.45	3	0.001
Cut & fill glyphosate	-2.04393	-3.05802 to -1.02985	3.95	0.000	16.77	3	0.001
Imazapyr alone	-3.34103	-5.21545 to -1.46662	3.49	0.000	5.57	4	0.234
Imazapyr + glyphosate	-2.55507	-3.35729 to -1.75285	6.24	0.000	4.31	5	0.506

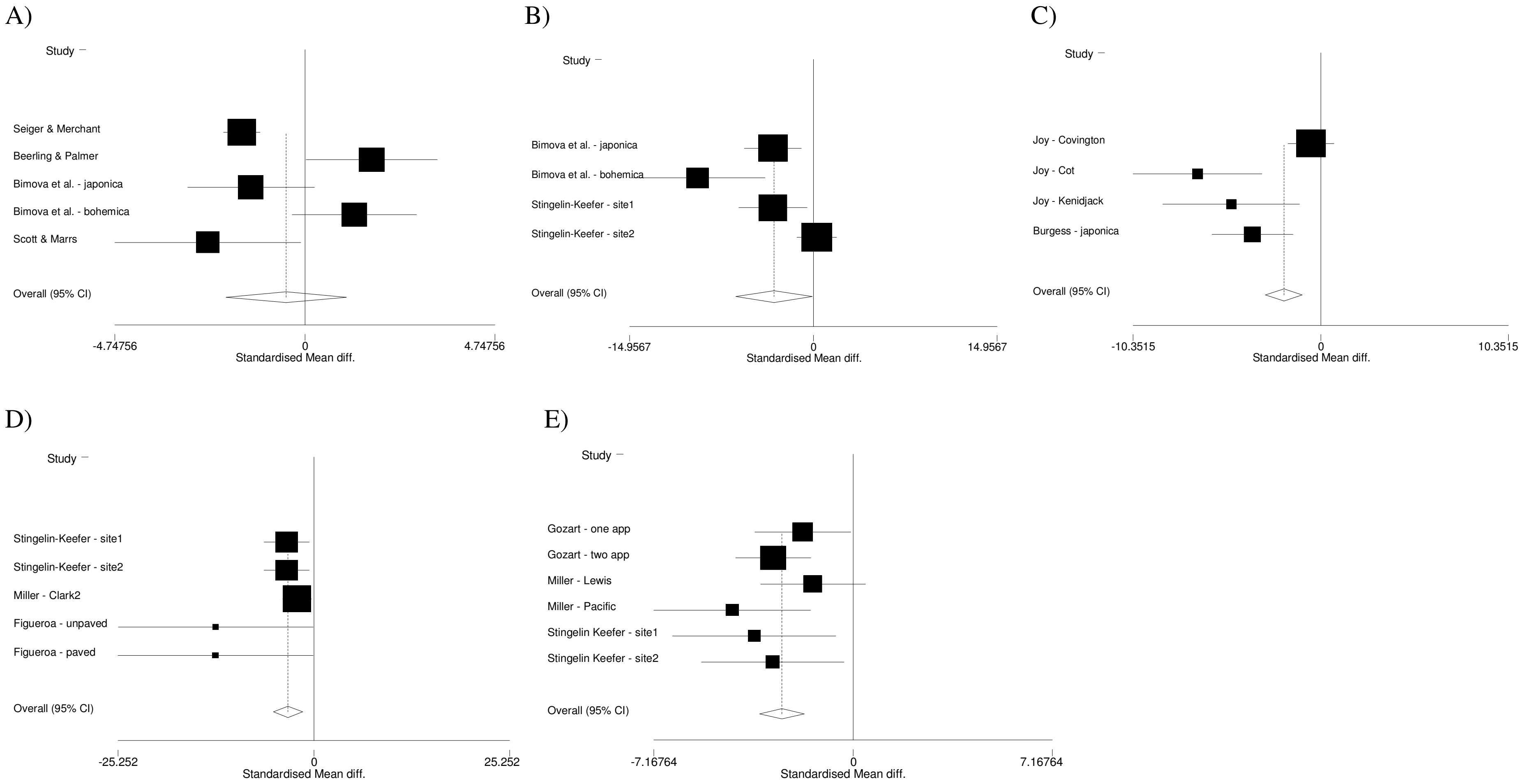

Figure 3: Forrest plots showing study effect sizes for interventions other than glyphosate treatment (compared to no intervention or before-treatment measurements): A) Cutting, B) Cut and spray regrowth with glyphosate, C) Cut and fill stems with glyphosate, D) Imazapyr alone, and E) Imazapyr and glyphosate combined.

4.4 Multivariate analyses

The DCA reveals no clear relationships in the general structure of the complete Japanese and hybrid knotweed data set. Cumulative variance of the first and second axes is low (0.64%, eigenvalues axis 1: 0.073, axis 2: 0.042), suggesting considerable variation between studies in terms of presence or absence of variables. Duration of control and time between multiple applications are significantly related to the first axis (duration: $r=0.931$, time: $r=0.316$, both $p<0.05$), but no other variables have correlations greater than 0.3 with the initial axes. TWINSPAN confirms that time between combination treatments is an important variable, providing a classification of the samples high in the hierarchy of divisions, and did not reveal any clear relationship between effectiveness of control and other variables.

The CCA provided a method of direct gradient analysis and verifies that there are no significant relationships between the effectiveness of knotweed control and ecological, methodological, and data quality variables (ter Braak & Smilauer, 2002). The first CCA axis has an eigenvalue of 0.007 ($p>0.1$), whilst the second axis has an eigenvalue of 0.003 ($p<0.006$), equating to 1.2% of total variance. The correlation between effectiveness and study variables on the second axis is 0.2, but this is not significant ($p>0.06$).

4.5 Outcome of the review

Application of glyphosate alone, imazapyr alone, and the two herbicides combined produce statistically significant decreases in Japanese and hybrid knotweed abundance in the short-term (less than 24 months). The application of glyphosate into stems immediately after cutting or to regrowth also significantly reduces abundance over a similarly short timescale (less than 32-33 months). However, sample sizes are small, study variances are high and the mean differences between control and treatment outcomes (see Tables 2-7) are small in comparison with those required for complete eradication. Cutting did not achieve significant short-term (less than 30 months) decreases in abundance.

Duration of control does not significantly change the effectiveness of glyphosate, but the impact of timing of application is significant. Application in July as opposed to May appears on average to be more effective in reducing knotweed abundance. However, this effect disappears when considered alongside the duration of the control effort.

Glyphosate application has less effect on hybrid knotweed than Japanese knotweed. Back-crosses with the variety ‘Crimson Beauty’ appear to be more resilient than Bohemian knotweed. However, these differences are not statistically significant and the effect sizes derived from Burgess (2005a, 2005b) and from Miller (2005) indicate there is little difference between control of the hybrid and its parent within the same study. This suggests that apparent differences in hybrid response to glyphosate application could be related to other factors, including site differences.

No clear patterns of the effectiveness of any particular treatment could be discerned using DCA on all available evidence. Furthermore, CCA demonstrates that there are no statistically significant relationships between effectiveness and the measured ecological and methodological variables. This reflects the paucity of high quality, long-term studies on the control and eradication of Japanese and hybrid knotweed.

5. DISCUSSION

5.1 Evidence of effectiveness

5.2.1 Effectiveness of interventions

Available evidence suggests that applications of the six different control methodologies considered in this review will not eradicate Japanese or hybrid knotweed in the short-term. Analyses of available data suggest that cutting treatments alone do not result in significant decreases in Japanese knotweed abundance. Statistically significant decreases in Japanese and hybrid knotweed abundance can be achieved by short-term applications of glyphosate, imazapyr, imazapyr + glyphosate, cutting followed by filling stems with glyphosate, and cutting followed by spraying regrowth with glyphosate. However, the impacts of these treatments may or may not be ecologically significant, and there is no robust evidence available regarding their long-term effectiveness. This reflects the small number of individual effect sizes, the limitations of the pooled studies (particularly confounded baselines and short timescales), and the high heterogeneity between included studies. The meta-analyses demonstrate that existing available evidence is insufficient to derive generic evidence-based management guidance for these particular techniques.

These conclusions are supported by multivariate analysis of lower quality data from a wider range of sources. Variation in effectiveness of treatments used against knotweed is evident both within and between treatments, but this variation could not be linked to any ecological or intervention-related variables.

5.2.2 Reasons for variation in effectiveness

Timing of control influences the effectiveness of glyphosate application, with application later in the year appearing to have a more significant effect on knotweed abundance. However, the effect is no longer significant when considered alongside the duration of control. This relationship should be treated cautiously, as it could be confounded by one of the many variables that differed between the included studies.

No conclusive evidence was found for differences in effectiveness of management techniques due to taxonomic variation.

5.2 Review limitations

The meta-analyses provide no evidence that eradication can be achieved within a short (typically less than 18 months) timeframe using these six particular treatment methods. There is a paucity of information regarding the overall effectiveness of knotweed control techniques in the medium (5-10 years) or long term, with the vast majority of information derived from studies of less than 3 years' duration. This problem is exacerbated by the lack of studies investigating rhizome response, as above ground abundance variables are likely to exhibit rapid fluctuation (i.e. decline and recovery) in comparison to the rhizomes. Rhizome ingression into treatment plots was also not addressed within any studies used in the meta-analyses. Therefore, these short-term studies of above ground abundance are likely to over-estimate the effectiveness of knotweed control.

Small sample sizes within each of the meta-analyses present problems of confounding and limit the general applicability of the results. Further analysis, which included less robust data, was severely constrained by lack of standardised reporting. Missing values in the multivariate synthesis were often substituted with averages or modes of data from other studies, or by using imprecise estimates of values as an alternative to exclusion. Information on some important variables (e.g. herbicide dosage) was so poorly reported that these variables were excluded altogether; thus, no clear patterns emerged from the resultant noise, highlighting the lack of robust available evidence.

The impact of Japanese knotweed management on other species (plant and animal) was an area that could not be effectively covered by this review. Several studies included measurements of change in plant cover during or after knotweed control. It would be valuable to assess this information, if the studies were of longer duration, as the issues of non-target damage and recovery of vegetation due to control programmes are important. There was also limited information on the cost-effectiveness of Japanese knotweed management. Further data would be required to adequately assess the cost-effectiveness of the different treatments assessed in the meta-analyses.

6. REVIEWERS' CONCLUSIONS

6.1 Implications for management, conservation and monitoring

In-situ eradication under different timescales, identified as situations under which to evaluate Japanese knotweed control and eradication (contexts 1, 2 and 3 in Section 3.1), was partially addressed by all of the meta-analyses conducted. These analyses provide no evidence that short-term eradication can be achieved by any of the six interventions considered. For the use of glyphosate, this result is consistent with generic guidance (e.g. Environment Agency and Cornwall County Council, 2001; Environment Agency, 2006). However, this review has also not found any evidence of effectiveness of any of the six interventions in the long term. In this sense, the available evidence fails to support, but does not contradict, generic guidance for the use of glyphosate.

This review could not readily assess all the different management contexts as required by practitioners (listed in section 3.1), as robust data that adequately dealt with each situation could not be located. Very little information was found investigating the use of excavation (context 4) and barriers (context 6), despite their widespread commercial use. Few studies noted they were exclusively located near watercourses, and hence context 5 could not be assessed.

In-situ treatment by a non-chemical method would protect adjacent more favourable vegetation, and hence context 7 was partially addressed by the cutting meta-analysis, as. This analysis indicates, however, that the impact of cutting in the short-term is ineffective. Herbicides are often applied as an injection, as some authors suggest that this more-directed approach is beneficial to surrounding vegetation (Joy, 2002;

Burgess, 2005a, 2005b; Gozart, 2005; Miller, 2005). However, meta-analyses of glyphosate applied as a spray or injection, or added directly into cut stems, showed limited short-term impacts on knotweed abundance. In Europe, imazapyr will soon no longer be available for use. While its use as an injection could be considered under context 7, meta-analysis of imazapyr spray indicated that short-term effects are minimal.

Meta-regression suggests that later application of glyphosate may increase its effectiveness. This is consistent with guidance, which advises application late in the growing season (e.g. Seiger, 1991; Child and Wade, 2000; English Nature, 2003; Environment Agency, 2006). However, the evidence for this was limited and should be treated with caution pending further research.

It has been reported that Bohemian knotweed regenerates more readily than its parents, and is potentially more invasive and resistant to control (Bimova *et al.*, 2001, 2003; Pysek *et al.*, 2003; Mandak *et al.*, 2004). However, there is no evidence that different taxonomic variants of knotweed (Japanese knotweed compared with its hybrids, Bohemian knotweed and back-crosses with *F. japonica* var. 'Crimson Beauty') have a differential response to glyphosate application.

Much of the literature collated as part of this systematic review was derived from grey-literature sources, such as Internet reports and anecdotal evidence. A large number of articles were also derived from conference proceedings, rather than peer-reviewed journal papers. The large number of guidance documents collected as part of this review (see Appendix 4) indicates the scale of effort that has been put into Japanese knotweed management across the world, particularly in the USA and UK. It is apparent that many of the organisations involved have had long-running management programmes with associated monitoring. The authors of this review are aware of control methods in use other than the six methods analysed in this review. However, as some monitoring results are not made readily available, the effectiveness of the full range of control and eradication methods currently implemented cannot be tested. Readers must therefore put the evidence presented here into a broader context of poor data accessibility.

This review highlights the importance of making control and eradication programme monitoring data more readily available, so that it can be effectively evaluated within a systematic review such as this one, or be more generally utilised by the stakeholder community. This includes as unpublished organisational reports, conference proceedings, and web-based materials (e.g. on www.ConservationEvidence.com, the Invasive Non-native Species in the UK website, or similar invasive species sites), as well as peer-reviewed publications.

Contact with the Cornwall (Japanese) Knotweed Forum in the UK has noted that they are currently compiling years of research into a 'Best Practice' protocol and other associated publications (J. Macfarlane, pers. comm.). Control work conducted by The Nature Conservancy in the USA is also being compiled, although this work has not systematically differentiated between Japanese knotweed and hybrids (D. Salzer and J. Soll, pers. comm.). The addition of this and other material may provide evidence for a future update of this systematic review.

6.2 Implications for research

This review highlights a lack of readily-available, long-term, robust, controlled experiments assessing the effects of the full range of management techniques used against Japanese and hybrid knotweed. As such, it emphasises important deficiencies within the current body of evidence, as shown by meta-analysis and multivariate synthesis of all available evidence for the control and eradication of these knotweed species.

Of 74 articles located concerning the control and eradication of Japanese and hybrid knotweed, only one study included within the review reported on 10 years of management (Baker, 1988), and another reported on a 4 year trial (Natural Biodiversity, year unknown). All other studies reported on 3 or less years of management, with the majority being approximately 12-18 months long. Short-term assessments investigating stem density and other visible evidence of treatment effectiveness do not provide information on rhizome impacts. Only one experiment was identified that investigated the impacts of treatments on below ground biomass. Seiger and Merchant (1997) looked at the impact of cutting on rhizomes; however, this was performed over periods of less than 6 months using ex-situ pieces of rhizome rather than a natural infestation of knotweed. This aspect of monitoring needs to be addressed in experiments or control programmes conducted on Japanese and hybrid knotweed. Large, long-term, well-replicated experiments would be required to show change in rhizome biomass, and destructive sub-sampling of the treatments and control would be needed every year to show the real impacts of management. Rhizome ingression from outside the study and between study plots also needs to be adequately addressed in any future research. A minimum patch size for treatments would need to be established to address this, which includes a buffer zone between patches. The Environment Agency (2006) notes that rhizomes can extend from anywhere between 0.5-10m away from the main plant. However, the distance of rhizome spread from a patch can be as far as 15-20m (Locandro (1973) and Conolly (1977), cited in Seiger (1991)). More adequate recording and reporting of variables are also required in order to more effectively assess the impacts of treatments. This includes baseline information within studies (especially regarding initial abundance measures), more comparable information on herbicide dosage rates (i.e. kilograms of active ingredient per hectare), differences in application methods (e.g. spray or injection; are both top and bottom of leaves sprayed?), and the effects of treatments over longer time periods,

A large, well-replicated experiment or monitoring programme examined over a long time period could also be used to test a range of different factors that may influence Japanese knotweed control and eradication. Such factors could include testing different techniques and types of herbicide, mechanical, manual and grazing control, plus combinations of these methods. Other aspects could include different herbicide active ingredients, and the impacts of timing, number of and time between applications, and duration of the control effort. If such an experiment were conducted over multiple sites, other factors such as species differences, size of infestation, techniques for sensitive and non-sensitive areas, and the geographical and environmental factors identified in the secondary objective of this review could also be adequately investigated. Considering the widespread invasion of both Japanese and Bohemian knotweed, and possibly other varieties and hybrids, it is recommended that collaboration and joint funding between stakeholder groups across and between countries be used to achieve the multi-site aspect of this research. Considering the substantial amount of money that is already invested in knotweed control, it would be worthwhile to provide funding for developing more effective ways of managing the problem under different circumstances.

Cutting and spraying regrowth with herbicide is a technique that is advocated by several guidance sources (e.g. Welsh Development Agency, 1998; Child and Wade, 2000). There is also support within current practice and guidance for the use of cutting and filling stems with glyphosate (e.g. Ford and Renals, 2001; Cornwall Knotweed Forum website), or by direct injection into live stems (e.g. Loveland, 2006), in order to provide a more directed chemical approach that may be useful for protecting nearby vegetation or sensitive areas such as watercourses. The latter technique is in use in the USA but apparently not in Europe. The direct injection technique was included in the glyphosate meta-analysis on both Japanese and hybrid knotweed. Some studies have investigated the effects on neighbouring vegetation of a more-directed approach to herbicide use (Joy, 2002; Burgess, 2005a, 2005b; Gozart, 2005; Miller, 2005). These techniques appear to be in general use, but there is very little evidence available to assess either of the cutting techniques or the injection method, nor were the timeframes long enough to be certain of eradication. All meta-analyses for these techniques demonstrated a significant effect of treatment, and more research could provide data to make these analyses more robust. Particular aspects that require further research using well-designed trials should involve differences in methodology, including direct injection, cut and immediate herbicide into or onto stems, and cutting followed by spraying of regrowth some time later.

Evidence for the use of excavation and other digging techniques to eradicate Japanese knotweed, including those that combine excavation or digging with herbicide use, was very limited. Further research evidence of the value of these techniques over other less-expensive management options needs to be provided. This also applies to root barriers and other methods of covering the infestations. These techniques appear to be in common commercial use and are recommended by guidance documents (e.g. Welsh Development Agency, 1998; Environment Agency, 2006), but there is little evidence available to support their effectiveness.

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8. POTENTIAL CONFLICTS OF INTEREST AND SOURCES OF SUPPORT

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10. APPENDICES

APPENDIX 1. SEARCH STRATEGY DETAILING SEARCH TERMS USED FOR EACH SEARCH, DATES SEARCHED AND NUMBER OF ITEMS RETRIEVED

Table 1. Search results table, including date searching was completed and number of results returned per information source.

Search database/organisation	Date searched	Results returned (inc. duplicates)
Electronic databases		
Agricola	9/1/06	155
CAB Abstracts	12/01/06	625
Digital Dissertations	14/12/06	16
Index to Theses	14/12/06	8
ISI Web of Knowledge - ISI Proceedings	14/12/06	42
ISI Web of Knowledge – Web of Science	14/12/06	293
JSTOR	16/12/06	141
Science Direct	21/12/06	245
Scirus (all journal sources)	22/12/06	256
Scopus	14/12/06	309
Internet resources		
All the Web	04/05/06	1 530
Dogpile	05/05/06	291
Google Scholar	04/05/06	42 577
Scirus (all web sources)	11-12/04/06	3 588
Other electronic resources and catalogues		
Blackwell Synergy	March-May 2006	103
ConservationEvidence.com	21/12/06	4
Copac	9/1/06	51
Directory of Open Access Journals	21/12/06	0
“Wildlink” catalogue	03/03/06	84
Elsevier	March-May 2006	0
EUNIS database	March-May 2006	0
iSpecies	March-May 2006	5
SpringerLink	March-May 2006	28
Organisational searches		
Sites searched using terms	March-May 2006	886
Sites searched by following links	March-May 2006	Numbers not retrievable
Specialist sources		
Sites searched using terms	March-May 2006	739
Sites searched by following links	March-May 2006	Numbers not retrievable

Table 2. Summary of Japanese knotweed search terms (* indicates the use of a wildcard function)

'knotweed'
Biotechnology and Biological Sciences Research Council (BBSRC)
British Waterways
Defence Science and Technology Laboratory (DSTL)
Environment Planning & Countryside Wales
Forest Research
The Macaulay Institute
Natural Environment Research Council (NERC)
Network Rail
Royal Horticultural Society
Sea Grant Nonindigenous Species Site (SGNIS)
UK Biodiversity Action Plan
Welsh Assembly Government
World Wide Fund for Nature (WWF)

'Japanese knotweed' ***(with or without AND, depending on search engine)***
Centre for Ecology & Hydrology (CEH)
Elsevier
HDRA Organic Weeds
NBII Invasive Species Information Node
Northern Ireland Dept. of Environment
Northern Ireland Environment and Heritage Service (EHS)
Pennsylvania State University

'Fallopia japonica'
iSpecies
ISSG's Global Invasive Species Database

'Polygonum cuspidatum'
NISBase: Nonindigenous Species Database Network

'Japanese knotweed', 'Fallopia japonica'
Northern Ireland Executive

'Fallopia japonica', 'Polygonum cuspidatum'
National Institute of Invasive Species Science

'knotweed', 'Fallopia japonica', 'Reynoutria japonica'
European Nature Information System database V2 (EUNIS)

'Fallopia japonica', 'Japanese knotweed' ***plus search in*** **'Cases – General Issue – Invasive Species'**
ConservationEvidence.com

‘Fallopia AND japonica’, ‘Polygonum AND cuspidatum’, ‘Reynoutria AND japonica’, ‘Japanese AND knotweed’ ***(with or without AND or comma, depending on search engine)***
Blackwell Synergy
English Nature (EN)
Forestry Commision GB
Government of Ireland
Joint Nature Conservation Committee (JNCC)
National Assembly for Wales
Scottish Executive Environment and Rural Affairs Department (SEERAD)
Scottish Natural Heritage (SNH)
SpringerLink
USDA Forest Services

‘Fallopia AND japonica AND control*’, ‘Polygonum AND cuspidatum AND control*’, ‘Reynoutria AND japonica AND control*’, ‘Japanese AND knotweed AND control*’
Dept. for Environment Food and Rural Affairs (Defra)
Europa

‘“Fallopia japonica” AND control*’, ‘“Polygonum cuspidatum” AND control*’, ‘“Reynoutria japonica” AND control*’, ‘“Japanese knotweed” AND control*’
Scirus (all web sources)

‘Fallopia AND japonica’, ‘Polygonum AND cuspidatum’, ‘Reynoutria AND japonica’, ‘Japanese AND knotweed’, ‘Fallopia AND japonica AND control’, ‘Polygonum AND cuspidatum AND control’, ‘Reynoutria AND japonica AND control’, ‘Japanese AND knotweed AND control’ ***(with or without AND or comma, depending on search engine)***
ADAS
Countryside Council for Wales (CCW)
Dept. Agriculture and Rural Development (DARD)
Directory of Open Access Journals
Environment Agency (EA)
Irish Environmental Protection Agency (EPA)
Royal Society for the Protection of Birds (RSPB)
Scottish Environmental Protection Agency (SEPA)

‘Fallopia AND japonica’, ‘Polygonum AND cuspidatum’, ‘Reynoutria AND japonica’, ‘Japanese AND knotweed’, ‘Fallopia AND japonica AND control*’, ‘Polygonum AND cuspidatum AND control*’, ‘Reynoutria AND japonica AND control*’, ‘Japanese AND knotweed AND control*’
Agricola
CAB Abstracts
Copac
Digital Dissertations Online
English Nature’s “Wildlink”
Index to Theses Online
ISI Web of Knowledge (including ISI Web of Science and ISI Proceedings searches)
JSTOR

Science Direct
Scirus (all journal sources)
Scopus

'Fallopia AND japonica', 'Polygonum AND cuspidatum', 'Reynoutria AND japonica', 'Japanese AND knotweed', 'Fallopia AND japonica AND ANY OF control controlled controlling', 'Polygonum AND cuspidatum AND ANY OF control controlled controlling', 'Reynoutria AND japonica AND ANY OF control controlled controlling', 'Japanese AND knotweed AND ANY OF control controlled controlling' ***(with or without AND, depending on search engine; control terms could also be separated by OR)***
European Environment Agency
The National Trust

'"Fallopia japonica" AND (control OR controlled OR controlling)', '"Polygonum cuspidatum" AND (control OR controlled OR controlling)', '"Reynoutria japonica" AND (control OR controlled OR controlling)', '"Japanese knotweed" AND (control OR controlled OR controlling)' ***(engine variations of AND were 'AND ANY OF' or 'AT LEAST ONE OF; OR was used depending on search engine functionality')***
All the Web
Dogpile
Google Scholar

Looked through all relevant pages
Clark County Washington
Cornwall County Council
Cornwall (Japanese) Knotweed Forum
Devon Knotweed Forum
Greene County Soil & Water Conservation District
Invasive Alien Plants (EMAPI conference information)
Japanese Knotweed Alliance
Japanese Knotweed Mailing List Archives
JK Injection Tools
Pennsylvania State University - Roadside Vegetation Management Research
Tweed Forum Invasives Project
Washington State Noxious Weed Control Board

Followed menu bar links to species
Ecology & Management of Invasive Plants
Introduced Species in the British Isles
Invasive & Exotic Species
Invasive Non-Native Species in the UK
Invasive Weeds UK
Noxious Weeds in the US and Canada
Pennsylvania State University – Integrated Pest Management
Pennsylvania State University – Weed Management
National Invasive Species Information Center (NISIC)
Washington State Dept. of Agriculture

APPENDIX 2. LITERATURE SCOPING SEARCHES FOR OTHER NAMES FOR JAPANESE KNOTWEED

Considering the variety of names that have been used for Japanese knotweed, including common and species names and the subspecies variety *Fallopia japonica var. compacta*, the extent of further information on the species needed to be scoped. Search terms used were:

1. Polygonum AND sieboldii
2. Polygonum AND japonicum
3. Polygonum AND (zuccharini OR zuccarinii)
4. Pleuropterus AND zuccarinii
5. Pleuropterus AND cuspidatus
6. Polygorum AND reynoutria
7. Polygonum AND reynoutria
8. Fallopia AND compacta
9. Japanese AND (fleece flower OR fleeceflower)
10. “fleece flower” OR fleeceflower
11. “Elephant ear bamboo”
12. “Mexican bamboo”
13. “crimson beauty”
14. “donkey rhubarb”
15. “Sally rhubarb”
16. “gypsy rhubarb”
17. “Hancock’s curse”
18. “Pysen saethwr”

The following common names were found after the scoping search had been conducted, and hence were not scoped:
German sausage, huzhang , itadori , Japanese bamboo, Japanese polygonum, kontiki bamboo, peashooter plant, renouée du Japon, reynoutria fleece flower

Table 1. Results of scoping search for other names for Japanese knotweed. Duplicate references were removed from individual database searches prior to compilation in a central EndNote library.

Search engine	Term 1	Term 2	Term 3	Term 4	Term 5	Term 6	Term 7	Term 8	Term 9
Agricola	0	0	0	0	0	0	0	0	2
Science Direct	0	0	0	0	0	0	3	2	0
Scopus	0	3	0	0	0	0	7	6	0
Web of Knowledge – Web of Science	1	1	0	0	0	0	15	5	0
Web of Knowledge - ISI Proceedings	0	0	0	0	0	0	1	0	0
Term Total	*1*	*4*	*0*	*0*	*0*	*0*	*26*	*13*	*2*

Search engine	Term 10	Term 11	Term 12	Term 13	Term 14	Term 15	Term 16	Term 17	Term 18
Agricola	2	0	4	2	0	0	0	0	0
Science Direct	3	0	1	1	0	0	0	0	0
Scopus	26	0	1	0	0	0	0	0	0
Web of Knowledge – Web of Science	3	0	2	1	0	0	0	0	0
Web of Knowledge - ISI Proceedings	0	0	0	0	0	0	0	0	0
Term Total	*34*	*0*	*8*	*4*	*0*	*0*	*0*	*0*	*0*
Total library (with duplicates)					**74**				
Total library (no duplicates)					**56**				

APPENDIX 3. LITERATURE SCOPING SEARCH FOR HYBRID SPECIES OF JAPANESE KNOTWEED

Japanese knotweed has been demonstrated to create at least two known hybrid species. When crossed with *Fallopia (Reynoutria) sachalinensis* (also known as *Polygonum sachalinense*), it produces *F. (R.) x bohemica* (also known as *Polygonum bohemicum, F. (R.) x vivax*, or Bohemian knotweed). Hybridisation with *Fallopia (Reynoutria) baldschuanica* produces *Fallopia x conollyana* (also known as the Haringey or Railway knotweed). The following search terms were scoped:

1. (Fallopia OR Reynoutria) AND bohemica
3. (Fallopia OR Reynoutria) AND vivax
4. (Fallopia OR Reynoutria) AND conollyana
5. Polygonum AND bohemicum

Table 2. Results of scoping search for hybrids of Japanese knotweed. Duplicate references were removed from individual database searches prior to compilation in a central EndNote library.

Search engine	Term 1	Term 2	Term 3	Term 4
Agricola	1	0	0	0
CAB Abstracts	19	1	1	1
JSTOR	1	0	0	1
Science Direct	4	1	0	0
Scirus – journals only	3	0	0	0
Scopus	11	1	0	1
Web of Knowledge – Web of Science	9	0	0	1
Web of Knowledge - ISI Proceedings	4	0	0	0
Term Total	*52*	*3*	*1*	*4*
Total library (with duplicates)			**39**	
Total library (no duplicates)			**24**	

APPENDIX 4. REFERENCE LIST OF GUIDANCE DOCUMENTS, INCLUDING TRADITIONAL REVIEWS

Alaska Natural Heritage Program. Polygonum cuspidatum. http://akweeds.uaa.alaska.edu/pdfs/species_bios_pdfs/Species_bios_POCU.pdf [Accessed 4 May 2006]

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APPENDIX 5. DATA EXTRACTION TABLES FOR ALL STUDIES INCLUDED IN META-ANALYSES

<table>
<tr><th>Reference</th><th colspan="6">Beerling, D.J. and Palmer, J.P. 1994. Status of Fallopia japonica (Japanese knotweed) in Wales. In: Ecology and Management of Invasive Riverside Plants. L.C. de Waal, L.E. Child, P.M. Wade and J.H. Brock (eds). Pp. 199-211. John Wiley & Sons Ltd. Chichester, UK.</th></tr>
<tr><td>Location</td><td colspan="6">Banks of the River Sirhowy at Cwmfelinfach, near Caerphilly, UK (National Grid Reference ST 188 913)</td></tr>
<tr><td>Subject</td><td colspan="6"><i>Fallopia japonica</i> (Japanese knotweed)</td></tr>
<tr><td>Intervention</td><td colspan="6">Cutting</td></tr>
<tr><td>Methodology</td><td colspan="6">Controlled Trial extracted as a Site Comparison. The circumference of 9 stands of knotweed were estimated. Increase in radius of stands was measured 1 and 2 years after experiment start. Three stands were cut once in June after the first year measurement, and six were left uncut.</td></tr>
<tr><td>Data timescale</td><td colspan="6">24 months</td></tr>
<tr><td>Baseline comparison</td><td colspan="6">Initial circumference for each stand is presented.</td></tr>
<tr><td>Replication</td><td colspan="6">Three cut stands, six untreated controls</td></tr>
<tr><td>Parameter of abundance</td><td colspan="6">Increase in radius of stands derived from circumference measures (cm)</td></tr>
<tr><td>Outcomes</td><td colspan="3">Treatment</td><td colspan="3">Control</td></tr>
<tr><td></td><td>n</td><td>m</td><td>sd</td><td>n</td><td>m</td><td>sd</td></tr>
<tr><td>Cutting</td><td>3</td><td>97.68</td><td>65.75</td><td>6</td><td>36.49</td><td>12.54</td></tr>
<tr><td>Reasons for heterogeneity</td><td colspan="6">habitat type (river bank), temperature (?), rainfall (?), soil moisture (?), soil type (?), ground slope (?), shading (?), latitude/longitude (ST 188 913), altitude (?), age of stand (?), height of stand (?), density of knotweed at start (?), size of controlled area (?), previous control (?), duration of control (24 months), effort of control (single cut), timing of control (June), herbicide type (N/A), herbicide application method (N/A), concentration of herbicide (N/A), number of herbicide applications (N/A), mechanical techniques (unspecified cutting method), no. applications/cuts (one), type of grazer (N/A), hybridisation (N/A), species variety (var. <i>japonica</i>).</td></tr>
<tr><td>Extraction</td><td colspan="6">Increase in radius size for each stand at the end of the second year was extracted from Figure 3.1.4 in Beerling's thesis, as the larger scale made extraction easier (equivalent data to Figure 20.3 in paper). There is some error associated with reading values off the graph. Means and variances were calculated for cut and control stands using data presented.</td></tr>
<tr><td>Sources of bias</td><td colspan="6">Timescale is short therefore do not know long-term effects of treatment. Mean initial circumference for control stands was almost double the mean for cut stands. Stands were assumed to be circular in size for circumference measures.</td></tr>
</table>

Notes	Other data presented but not extracted related to: distribution, type of damage caused, type of management used, viability of rhizome fragments and whole corms, and a case study of distribution and damage caused.
References	Extra information on methodology was derived from: Beerling, D. J. (1991). The ecology and control of Japanese knotweed (Reynoutria Japonica Houtt.) and Himalayan Balsam (Impatiens Glandulifera Royle) on river banks in South Wales. Cardiff, University of Wales, College of Cardiff.

Reference	Bimova, K., Mandak, B. and Pysek, P. 2001. Experimental control of Reynoutria congeners: A comparative study of a hybrid and its parents. In: Plant Invasions: Species Ecology and Ecosystem Management. G. Brundu, J. Brock, I. Camarda, L. Child and M. Wade (eds). Pp. 283-290. Backhuys Publishers. Leiden, The Netherlands.
Location	Surroundings of Prague, Central Bohemia, Czech Republic (50˚00'N, 14˚30'E)
Subject	*Fallopia japonica* (Japanese knotweed) and *Fallopia x bohemica* (Bohemian knotweed)
Intervention	Cutting, digging, cutting + glyphosate foliar spray on regrowth, digging + glyphosate foliar spray on regrowth
Methodology	Randomised Controlled Trial extracted as a Site Comparison. Four sites each of *F. japonica* and *F. x bohemica* were selected. Each site had 5 sampling plots of 4m^2 in size, randomly located in monospecific stands. Each plot was assigned one of four treatments or left as an untreated control. Standing dead stems were removed before experiment started in March, and all stems were removed in October each year. Cutting was applied once in May and spraying once in July over two years. Monitoring occurred 5 and 17 months after the first treatment.
Data timescale	17 months
Baseline comparison	No baseline information is presented.
Replication	Four plots of each treatment and one untreated plot per site, four sites per species.
Parameter of abundance	Stem density (shoots.m^{-2})

Outcomes	Treatment			Control		
	n	m	sd	n	m	sd
F. japonica (cutting)	4	8.34	1.67	4	11.34	2.67
F. x bohemica (cutting)	4	17	3	4	14	1.67
F. japonica (cut & spray)	4	4	1.67	4	11.34	2.67
F. x bohemica (cut & spray)	4	2.33	0.67	4	14	1.67

Reasons for heterogeneity	habitat type (?), temperature (mean annual 9.2°C), rainfall (mean annual 490mm), soil moisture (?), soil type (?), ground slope (?), shading (?), latitude/longitude (50°00'N, 14°30'E), altitude (?), age of stand (?), height of stand (0.75-1m), density of knotweed at start (?), size of controlled area (16m^2 per treatment), previous control (?), duration of control (17 months), effort of control (one cut and/or one spray per year), timing of control (cut = May, spray = July), herbicide type (glyphosate), herbicide application method (long lance sprayer), concentration of herbicide (50mL per 100m^2 diluted at 12L/100m^2), number of herbicide applications (two), mechanical techniques (cut to ground level), no. applications/cuts (two), type of grazer (N/A), hybridisation (*F. x bohemica*), species variety (var. *japonica*).
Extraction	Mean stem density and standard deviation data were extracted from Figure 2. There is some error associated with reading values off the graph. Independent effect sizes were extractable for *F. japonica* and *F. x bohemica*. Non-independent data extracted for control plots for treatments per species, but as these were used in two separate meta-analyses, it does not present a problem.
Sources of bias	Timescale is short therefore do not know long-term effects of treatment. No data were presented regarding experimental blocks at start of trial, therefore there is no evidence that changes are related to interventions.
Notes	Other data presented but not extracted related to: digging treatment, digging + spraying treatment, treatments on *Fallopia sachalinensis* (Giant knotweed), and data from biomass (as % of control biomass). Statisitical results only are presented for weight of dry biomass, % cover of knotweed species and % cover of other species.
References	N/A

Reference	Burgess, P. 2005a. Efficacy Trials - Injection Method: Bohemian knotweed. Clark County Weed Management. http://www.co.clark.wa.us/weed/documents/efficacy/knotweed%20files/Treatment%20Data%20Boh-knotweed.pdf and http://www.co.clark.wa.us/weed/documents/efficacy/knotweed%20files/klineline-canebkdown.pdf
Location	East of Klineline Pond, North of 117th Street, between Highway 99 and 1-5, Clark County, Washington, USA.
Subject	*Fallopia x bohemica* (Bohemian knotweed)
Intervention	Injection of glyphosate
Methodology	Time Series extracted as a Site Comparison. Plots were injected in June with either 4mL or 6mL of 100% glyphosate concentrate. The number of stems treated was recorded. There were no untreated controls. Monitoring occurred 1.5 months after treatment.
Data timescale	1.5 months
Baseline comparison	Number of stems treated was presented.
Replication	Two 4mL plots, seven 6mL plots

Parameter of abundance	Number of stems					
Outcomes	Treatment			Control		
	n	m	sd	n	m	sd
Glyphosate 4mL	2	0	0.001	2	9	7.07
Glyphosate 6mL	7	0.86	1.21	7	50.57	24.62
Reasons for heterogeneity	habitat type (?), temperature (?), rainfall (?), soil moisture (?), soil type (?), ground slope (?), shading (?), latitude/longitude (?), altitude (?), age of stand (?), height of stand (4mL - 8 feet, 6mL - 9 feet), density of knotweed at start (?), size of controlled area (?), previous control (?), duration of control (1.5 months), effort of control (single), timing of control (June), herbicide type (glyphosate), herbicide application method (injection), concentration of herbicide (100% concentrate), number of herbicide applications (one), mechanical techniques (N/A), no. applications/cuts (N/A), type of grazer (N/A), hybridisation (*F. x bohemica*), species variety (N/A).					
Extraction	Raw before and after stem count data from separate table were used to calculate means and standard deviations per treatment. Due to 100% control in 4mL plots, standard deviation of zero was substituted with 0.001.					
Sources of bias	Timescale is very short therefore do not know long-term effects of treatment. No untreated control was included, therefore there is no evidence that changes are related to interventions.					
Notes	Other data presented but not extracted related to stem diameter.					
References	N/A					

Reference	Burgess, P. 2005b. Efficacy Trials - Injection Method: Knotweed. Clark County Weed Management. http://www.co.clark.wa.us/weed/documents/efficacy/knotweed%20files/155th%20Ave%20Knotweed%20Data.pdf
Location	NE 155th Avenue, Clark County, Washington, USA.
Subject	*Fallopia japonica* (Japanese knotweed)
Intervention	Injection of glyphosate, cut & fill stems with glyphosate
Methodology	Time Series extracted as a Site Comparison. Plots were injected in July with either 4mL or 5mL of 100% glyphosate concentrate. Other plots where stems were too small for injection were cut, and the stems filled with 1mL of 100% glyphosate concentrate. The number of stems treated was recorded. There were no untreated controls. Monitoring occurred 2 months after treatment.
Data timescale	2 months
Baseline comparison	Number of stems treated was presented.
Replication	Four cut & fill 1mL plots, three 4mL plots, four 5mL plots

Parameter of abundance	Number of stems					
Outcomes	Treatment			Control		
	n	m	sd	n	m	sd
Cut & fill glyphosate 1mL	5	0	0.001	5	1.2	0.45
Glyphosate 4mL	3	0	0.001	3	10	2
Glyphosate 5mL	4	0	0.001	4	12.25	7.59
Reasons for heterogeneity	habitat type (?), temperature (?), rainfall (?), soil moisture (?), soil type (?), ground slope (?), shading (?), latitude/longitude (?), altitude (?), age of stand (?), height of stand (1mL - 2.5 feet, 4mL - 8 feet, 5mL - 9 feet), density of knotweed at start (?), size of controlled area (?), previous control (?), duration of control (2 months), effort of control (single), timing of control (July), herbicide type (glyphosate), herbicide application method (injection or fill cut stem), concentration of herbicide (100% concentrate), number of herbicide applications (one), mechanical techniques (unspecified cutting method), no. applications/cuts (one), type of grazer (N/A), hybridisation (N/A), species variety (var. *japonica*).					
Extraction	Raw before and after stem count data from table were used to calculate means and standard deviations per treatment. Due to 100% control in all plots, standard deviation of zero was substituted with 0.001.					
Sources of bias	Cut & fill plots only had one or two stems per plot therefore replication is over-estimated. Timescale is very short therefore do not know long-term effects of treatment. No untreated control was included, therefore there is no evidence that changes are related to interventions.					
Notes	Other data presented but not extracted related to stem diameter.					
References	N/A					

Reference	Figueroa, P.F. 1989. Japanese knotweed herbicide screening trial applied as a roadside spray. *Proceedings of the Western Society of Weed Science* 42: 288-298.
Location	Weyerhaeuser Company's Cascade Region, Washington, USA: unpaved site - 4000 mainline logging road near junction with Tokul Road; paved site - 396 Drive SE between Reining Road at Snoqualmie Mill (sec 20, 29 T24N R8E)
Subject	*Fallopia japonica* (Japanese knotweed)
Intervention	Foliar spraying of clopyralid (at four dosage rates), imazapyr, dicamba, 2,4-D, and glyphosate

<table>
<tr><td>Methodology</td><td colspan="6">Controlled Trial extracted as a Site Comparison. Randomised block design featuring two blocks (paved and unpaved sites). Each block was randomly divided into 8 treatments and one untreated control plot. Plots were 4.6 x 4.6m, and bordered the roadways. Herbicide was applied once in June in one year. Monitoring occurred 11 months after treatment.</td></tr>
<tr><td>Data timescale</td><td colspan="6">11 months</td></tr>
<tr><td>Baseline comparison</td><td colspan="6">No baseline information is presented.</td></tr>
<tr><td>Replication</td><td colspan="6">Sampling per block of two sub-plots per treatment and control plots.</td></tr>
<tr><td>Parameter of abundance</td><td colspan="6">Stem density (shoots.m^{-2})</td></tr>
<tr><td>Outcomes</td><td colspan="3">Treatment</td><td colspan="3">Control</td></tr>
<tr><td></td><td>n</td><td>m</td><td>sd</td><td>n</td><td>m</td><td>sd</td></tr>
<tr><td>Paved glyphosate</td><td>2</td><td>3</td><td>1.41</td><td>2</td><td>9.5</td><td>0.71</td></tr>
<tr><td>Unpaved glyphosate</td><td>2</td><td>10.5</td><td>0.71</td><td>2</td><td>20.5</td><td>2.12</td></tr>
<tr><td>Paved imazapyr</td><td>2</td><td>0.5</td><td>0.71</td><td>2</td><td>9.5</td><td>0.71</td></tr>
<tr><td>Unpaved imazapyr</td><td>2</td><td>0.5</td><td>0.71</td><td>2</td><td>20.5</td><td>2.12</td></tr>
<tr><td>Reasons for heterogeneity</td><td colspan="6">habitat type (roadside - paved and unpaved), temperature (?), rainfall (?), soil moisture (well-drained), soil type (gravelly sandy loam to 60cm - Barneston soil series of deep, well-drained, coarse textured developed from loose gravelly glacial outwash material), ground slope (?), shading (?), latitude/longitude (29 T24N R8E), altitude (?), age of stand (?), height of stand (approx. 2m), density of knotweed at start (?), size of controlled area (21.16m^{2} per treatment per site), previous control (possibly periodic mowing), duration of control (11 months), effort of control (single application), timing of control (June), herbicide type (glyphosate, imazapyr), herbicide application method (backpack sprayer and gun with D4 nozzle with solid cone stream, pump pressure at 276kPa, rate 306L/km), concentration of herbicide (glyphosate 3.4kg ai/ha, imazapyr 0.6kg ai/ha), number of herbicide applications (one), mechanical techniques (N/A), no. applications/cuts (N/A), type of grazer (N/A), hybridisation (N/A), species variety (var. <i>japonica</i>).</td></tr>
<tr><td>Extraction</td><td colspan="6">Mean stem density and standard error data were extracted from Tables 3 and 4 for glyphosate and imazapyr treatments and the control plots. Non-independent data extracted for controls within blocks, but as this was used in two separate meta-analyses, it does not present a problem. Independent effect sizes were extractable for paved and unpaved sites.</td></tr>
<tr><td>Sources of bias</td><td colspan="6">Timescale is short therefore do not know long-term effects of treatment. No data were presented regarding experimental blocks at start of trial, therefore there is no evidence that changes are related to interventions. Level of replication is low.</td></tr>
<tr><td>Notes</td><td colspan="6">Other data presented but not extracted related to: clopyralid foliar spray treatment at 4 dosage rates, dicamba foliar spray treatment, 2,4-D foliar spray treatment, and data from maximum total stem height.</td></tr>
<tr><td>References</td><td colspan="6">N/A</td></tr>
</table>

<table>
<tr><th>Reference</th><th colspan="6">Gozart, C. (2006). Unpublished data for Bohemian knotweed control on East Fork and North Fork of the Lewis River and tributaries.</th></tr>
<tr><td>Location</td><td colspan="6">Washington, USA: East Fork and North Fork, Lewis River</td></tr>
<tr><td>Subject</td><td colspan="6"><i>Fallopia xbohemica</i> (Bohemian knotweed)</td></tr>
<tr><td>Intervention</td><td colspan="6">Injection and/or spray of glyphosate; foliar spray of imazapyr + glyphosate; foliar spray of imazapyr + glyphosate and injection of glyphosate (one plot also had injection of imazapyr)</td></tr>
<tr><td>Methodology</td><td colspan="6">Controlled Trial extracted as a Site Comparison. Plots of Bohemian knotweed were located throughout the area. Each plot measured 20 x 20 feet. There was one untreated control plot. Treatments were applied in July-September in Year 1, and in August Year 2 on multiple-application plots only. The number of stems treated was recorded. Monitoring occurred 22-24 months after treatment.</td></tr>
<tr><td>Data timescale</td><td colspan="6">Glyphosate = 23.5-23.75 months, imazapyr + glyphosate = 22.6-23 months</td></tr>
<tr><td>Baseline comparison</td><td colspan="6">Number of stems treated was presented.</td></tr>
<tr><td>Replication</td><td colspan="6">Glyphosate (one or two apps) = two plots each, imazapyr + glyphosate (one app) = four plots, imazapyr + glyphosate (two apps) = nine plots</td></tr>
<tr><td>Parameter of abundance</td><td colspan="6">Number of stems</td></tr>
<tr><td>Outcomes</td><td colspan="3">Treatment</td><td colspan="3">Control</td></tr>
<tr><td></td><td>n</td><td>m</td><td>sd</td><td>n</td><td>m</td><td>sd</td></tr>
<tr><td>Glyphosate (one app)</td><td>2</td><td>1</td><td>1.41</td><td>2</td><td>41</td><td>29.7</td></tr>
<tr><td>Glyphosate (two apps)</td><td>2</td><td>3</td><td>1.41</td><td>2</td><td>122.5</td><td>51.62</td></tr>
<tr><td>Imazapyr & glyphosate (one app)</td><td>4</td><td>9.25</td><td>8.18</td><td>4</td><td>69.75</td><td>46.56</td></tr>
<tr><td>Imazapyr & glyphosate (two apps)</td><td>9</td><td>3.11</td><td>4.17</td><td>9</td><td>110.33</td><td>52.66</td></tr>
<tr><td>Reasons for heterogeneity</td><td colspan="6">habitat type (riparian), temperature (?), rainfall (?), soil moisture (?), soil type (mostly sand and rock, some woodland soil or deep soil), ground slope (?), shading (?), latitude/longitude (?), altitude (?), age of stand (?), height of stand (?), density of knotweed at start (?), size of controlled area (400ft^2 per plot), previous control (N/A), duration of control (22-24 months), effort of control (single per year), timing of control (Jul-Oct), herbicide type (glyphosate, imazapyr + glyphosate), herbicide application method (spray or injection), concentration of herbicide (glyphosate injection = 100% concentrate, glyphosate spray 4.5% solution, imazapyr + glyphosate spray = glyphosate 4.5% + imazapyr 1.5% solution, imazapyr injection unknown), number of herbicide applications (one or two), mechanical techniques (N/A), no. applications/cuts (N/A), type of grazer (N/A), hybridisation (<i>F. xbohemica</i>), species variety (N/A).</td></tr>
</table>

Extraction	Raw before and after stem count data supplied by author were used to calculate means and standard deviations per treatment. Only a single untreated control plot was presented, therefore data were extracted as a site comparison using before and after treatment information from treated plots only. Single and double applications of herbicides were extracted, as before and after data were related to individual plots allowing derivation of independent effect sizes from sites in the same catchment. Duration of experiment was derived from average number of months across all plots per treatment. Timing of application was derived from modal month of all plots treated with imazapyr + glyphosate. Month was not extracted for glyphosate applications as aggregation bias would have occurred from using the average of the two months in which herbicide was applied.
Sources of bias	Timescale is short therefore do not know long-term effects of treatment. Insufficient data were presented regarding an untreated control, therefore there is no evidence that changes are related to interventions.
Notes	Other data presented but not extracted related to: results after one year of treatment, effects of treatment on isolated clumps and stands and on type of regrowth, damage to neighbouring vegetation, and % native cover.
References	Extra information on methodology was derived from: Gozart, C. 2005. The 2004 East Fork Knotweed Control Project; Results Data. May 2005. http://www.jkinjectiontools.com/Research%20Docs/Lewis%20River%202004%20Results.doc

Reference	Joy, E. 2002. Development of Good Practice for the use of the injection method of herbicide application to control Japanese knotweed (Fallopia japonica). Camborne School of Mines. University of Exeter.
Location	National Trust property in Cornwall, UK: Cot and Kenidjack Valleys in West Penwith, and Covington Woods in Fowey, SE Cornwall.
Subject	*Fallopia japonica* (Japanese knotweed)
Intervention	Cut & fill stem with herbicides: glyphosate, 2,4D amine, triclopyr, picloram, sodium salt of asulam, diquat, and imazapyr.
Methodology	Time Series extracted as a Site Comparison. Plots were located in different sites throughout the area. Different treatments were applied to plots in each year, although a number received only glyphosate treatment. Plot sizes ranged, the maximum being 15 x 15m. There were no untreated controls. Treatments were applied in August - September, with cutting followed by immediate filling of stem with herbicide. Monitoring occurred approximately one month before applications started, and after treatments began at 9-10 months, 21-22 months, 23-24 months, and 32-33 months.
Data timescale	32-33 months
Baseline comparison	% cover before treatment was presented.
Replication	Covington 5 quadrats on one plot, Covington 5 plots, Kenidjack 3 plots
Parameter of abundance	% cover

Outcomes	Treatment			Control		
	n	m	sd	n	m	sd
Covington	5	22	22.8	5	38	34.21
Cot	5	0.28	0.23	5	75.8	15.71
Kenidjack	3	5	6.93	3	76	19.08
Reasons for heterogeneity	habitat type (?), temperature (?), rainfall (?), soil moisture (?), soil type (?), ground slope (?), shading (?), latitude/longitude (?), altitude (?), age of stand (?), height of stand (?), density of knotweed at start (?), size of controlled area (?), previous control (?), duration of control (32-33 months), effort of control (single per year), timing of control (August-September), herbicide type (glyphosate), herbicide application method (fill cut stem), concentration of herbicide (10x recommended concentration for spraying), number of herbicide applications (Covington = 2, Cot & Kenidjack = 3), mechanical techniques (unspecified cutting method), no. applications/cuts (Covington = 2, Cot & Kenidjack = 3), type of grazer (N/A), hybridisation (N/A), species variety (var. *japonica*).					
Extraction	Means and variances were calculated for glyphosate-treated only sites, using pre-treatment data presented in Appendix 4 and post-treatment data presented in 5. The required data was only available for 9 plots. Mean and variance for Covington plot F4 was calculated using 5 quadrats as replicates. Mean and variance for Cot site was calculated using means per plot (C1-C5) or whole plot data (pre-treatment only C5), providing 5 plots as replicates. Mean and variance for Kenindjack site were calculated using means per plot (K2, K5 and K6), providing three replicates. The results from multiple applications of glyphosate were used in order to data of the longest timescale.					
Sources of bias	Timescale is short therefore do not know long-term effects of treatment. No untreated control was included, therefore there is no evidence that changes are related to interventions.					
Notes	Other data presented but not extracted related to: number and % cover of other species, % cover of bare ground, number of crowns and stems of knotweed, height and diameter of stems. Number of stems data could not be used for meta-analysis as pre-treatment raw data was not presented and therefore variance could not be derived.					
References	N/A					

Reference	Miller, T. 2005. Evaluation of Knotweed Control Projects in Southwestern Washington. Northwestern Washington Research and Extension Center, Washington State University. http://agr.wa.gov/PlantsInsects/Weeds/Knotweed/docs/Knotweed_Evaluation_SW_WA.pdf
Location	Washington, USA: Upper and Lower East Fork Lewis River sites, Upper Cowlitz River, Willapa River, Washougal River and Beacon Rock.

Subject	*Fallopia japonica* (Japanese knotweed) and *Fallopia x bohemica* (Bohemian knotweed)					
Intervention	Injection of glyphosate, foliar spray of imazapyr, foliar spray of imazapyr + glyphosate					
Methodology	Time Series extracted as a Site Comparison. Four sites of Bohemian knotweed were each treated with one of four different treatments. Two Japanese knotweed sites were treated only with glyphosate injection. Each site had four plots, measuring 20 x 20 feet. There were no untreated controls. Treatments were applied once in July. Monitoring occurred 11 months after treatment.					
Data timescale	11 months					
Baseline comparison	Number of stems treated was presented.					
Replication	Four plots per site, except for Lewis imazapyr + glyphosate site, which had only three plots.					
Parameter of abundance	Number of stems					
Outcomes	Treatment			Control		
	n	m	sd	n	m	sd
Glyphosate (Beacon Rock, *F. japonica*)	4	14.25	6.81	4	38.5	9.32
Glyphosate (Upper Clark, *F. x bohemica*)	4	9	6.34	4	33.63	10.94
Glyphosate (Skamania, *F. japonica*)	4	21	13.13	4	58.13	30.6
Imazapyr (Lower Clark, *F. x bohemica*)	4	12.5	10.06	4	44	17.9
Imazapyr 0.75% & glyphosate 1.5% (Lewis, *F. x bohemica*)	3	12.83	16.17	3	64.33	47.72
Imazapyr 0.5% & glyphosate 2% (Pacific, *F. x bohemica*)	4	14.88	7.79	4	53.13	9.71

Reasons for heterogeneity	habitat type (?), temperature (?), rainfall (?), soil moisture (?), soil type (?), ground slope (?), shading (?), latitude/longitude (?), altitude (?), age of stand (?), height of stand (?), density of knotweed at start (?), size of controlled area (400ft^2 per site), previous control (?), duration of control (11 months), effort of control (single), timing of control (July), herbicide type (glyphosate, imazapyr, combination), herbicide application method (injection or spray), concentration of herbicide (glyphosate injection = 100% concentrate, imazapyr = 1.5% solution, combination1 = glyphosate 1.5% + imazapyr 0.75% solution, combination2 = glyphosate 2% + imazapyr 0.5% solution), number of herbicide applications (one), mechanical techniques (N/A), no. applications/cuts (N/A), type of grazer (N/A), hybridisation (*F. x bohemica*), species variety (var. *japonica*).
Extraction	Raw before and after stem count data supplied by author were used to calculate means and standard deviations per site/treatment. No post-treatment data were presented for one of the plots on the Lewis site, therefore only three replicates were used.
Sources of bias	Timescale is short therefore do not know long-term effects of treatment. No untreated control was included, therefore there is no evidence that changes are related to interventions.
Notes	Other data presented but not extracted related to: % control, stem diameter and stem height. Author confirmed questioned sites were Japanese knotweed.
References	N/A

Reference	Scott, R. and R.H. Marrs. 1984. Impact of Japanese knotweed and methods of control. *Aspects of Applied Biology* 5: 291-296.
Location	Cemetery in Manchester, UK.
Subject	*Fallopia japonica* (Japanese knotweed)
Intervention	Cutting; tebuthiuron pellets; foliar spraying of atrazine/aminotriazole, ammonium sulphamate, glyphosate, fosamine, picloram, asulam, triclopyr, simazine
Methodology	Randomised Controlled Trial extracted as Site Comparison. A randomised split-plot design of 11 plots was replicated over three blocks. Treatments were applied to plots; each sub-plot received one or two treatment applications. One non-independent untreated control plot (2 sub-plots) was included. Each sub-plot was 3 x 3m. Herbicide or cutting was applied in May over two years. Monitoring was conducted after the first treatment application at 12 weeks and at 15 months (12 weeks after second application).
Data timescale	15 months
Baseline comparison	No baseline information is presented.
Replication	Three fully-replicated blocks, therefore three replications for both one and two applications of treatments and the control.

Parameter of abundance	Stem density (shoots.m^{-2})					
Outcomes	Treatment			Control		
	n	m	sd	n	m	sd
Glyphosate (single)	3	40	22.52	3	31	3.46
Cutting (single)	3	15	8.66	3	31	3.46
Reasons for heterogeneity	habitat type (cemetery), temperature (?), rainfall (?), soil moisture (?), soil type (?), ground slope (?), shading (?), latitude/longitude (?), altitude (?), age of stand (?), height of stand (1.5m), density of knotweed at start (?), size of controlled area (9m^2 per sub-plot), previous control (?), duration of control (15 months), effort of control (single application per year), timing of control (May), herbicide type (glyphosate), herbicide application method (knapsack sprayer), concentration of herbicide (2.2kg/ha ai), number of herbicide applications (one), mechanical techniques (unspecified cutting method), no. applications/cuts (one), type of grazer (N/A), hybridisation (N/A), species variety (var. *japonica*).					
Extraction	Mean stem density and standard error data from single applications of glyphosate and cutting were extracted from Table 3, column '1982 only'. Non-independent data extracted for control sub-plots, but as this was used in two separate meta-analyses, it does not present a problem. A single application of both cutting and glyphosate was chosen to maintain independence by extracting only one effect size per study, and to examine the longest timescale presented.					
Sources of bias	Timescale is short therefore do not know long-term effects of treatment. No data were presented regarding experimental blocks at start of trial, therefore there is no evidence that changes are related to interventions.					
Notes	Other data presented but not extracted related to: one and two applications of other herbicides (tebuthiuron pellets; foliar spraying of atrazine/aminotriazole, ammonium sulphamate, glyphosate, fosamine, picloram, asulam, triclopyr, simazine), and data from mean and maximum stem height. Infestation of knotweed was noted as severe and continuous.					
References	N/A					

Reference	Seiger, L.A. and H.C. Merchant. 1997. Mechanical control of Japanese knotweed (Fallopia japonica [Houtt.] Ronse Decraene): Effects of cutting regime on rhizomatous reserves. *Natural Areas Journal* 17(4): 341-345.
Location	Washington DC, USA
Subject	*Fallopia japonica* (Japanese knotweed)
Intervention	Cutting

<table>
<tr><td>Methodology</td><td colspan="6">Randomised Controlled Trial extracted as Site Comparison. The experiment investigated the effects on biomass of number of cuts within a season, time of season cutting occurred, and interval between cuts. 240 rhizome fragments (approx. 1cm diameter and 3 nodes in length) were taken from a field population. Each fragment was planted in a pot in May, and was grown outdoors under ambient conditions. 30 rhizomes were assigned to each of 8 experimental groups, including untreated controls. Single cuts were applied in June, July or August, 28 days apart. Rhizomes were harvested after complete leaf loss (compared to other experiments, this was presumably in October and therefore 5.5 months after experiment start).</td></tr>
<tr><td>Data timescale</td><td colspan="6">5.5 months (assumed)</td></tr>
<tr><td>Baseline comparison</td><td colspan="6">No baseline information is presented.</td></tr>
<tr><td>Replication</td><td colspan="6">30 rhizomes were included in each experimental group, including the control. The mean biomass for the single cut treatment is the combined measurement from cutting in June, July and August, therefore replication is 90 rhizomes.</td></tr>
<tr><td>Parameter of abundance</td><td colspan="6">Below ground biomass (g)</td></tr>
<tr><td rowspan="3">Outcomes</td><td colspan="3">Treatment</td><td colspan="3">Control</td></tr>
<tr><td>n</td><td>m</td><td>sd</td><td>n</td><td>m</td><td>sd</td></tr>
<tr><td>90</td><td>20.01</td><td>7.78</td><td>30</td><td>31.24</td><td>4.49</td></tr>
<tr><td>Reasons for heterogeneity</td><td colspan="6">habitat type (?), temperature (?), rainfall (?), soil moisture (?), soil type (?), ground slope (?), shading (?), latitude/longitude (?), altitude (?), age of stand (transplanted, approx. 5 months), height of stand (N/A), density of knotweed at start (?), size of controlled area (?), previous control (none), duration of control (approx. 5 months), effort of control (single cut), timing of control (June, July & August cuts combined), herbicide type (N/A), herbicide application method (N/A), concentration of herbicide (N/A), number of herbicide applications (N/A), mechanical techniques (unspecified cutting method), no. applications/cuts (one), type of grazer (N/A), hybridisation (N/A), species variety (var. <i>japonica</i>).</td></tr>
<tr><td>Extraction</td><td colspan="6">Data was extracted for the single cut from Figure 3 as 1) mean biomass values were presented in the text as opposed to converting log-transformed values, 2) there would presumably be little difference between effect sizes generated from either figure on the basis of similarity in experiments for a single cut, 3) we wanted to examine the longest timescale presented, 4) we wanted to maintain independence by extracting only one effect size per study and 5) we did not want to overweight this study. There is some error associated with reading standard error values off the graph.</td></tr>
<tr><td>Sources of bias</td><td colspan="6">No biomass data is presented from before treatments, although the number and size of rhizome fragments was controlled. The below ground biomass measure should be interpreted cautiously in comparison to other outcome measures used in the cutting meta-analysis. The experiment was not performed under natural conditions i.e. pot-grown rhizomes as opposed to naturally-growing stands. Data from three cutting timings was pooled; however, it was noted that the effect of cutting timing on biomass was not significant. Replication is high due to the number of rhizomes assessed and should be interpreted cautiously. Timescale is very short therefore do not know long-term effects of treatment.</td></tr>
</table>

Notes	Other data presented but not extracted related to: effects of number of cuts, timing of cut within season and interval between cuts for double and triple applications; single cut at different times within season; and seasonal patterns of biomass accumulation in uncut rhizomes.
References	N/A

Reference	Stingelin Keefer, J. 2002. Effects of rate and timing of glyphosate and imazapyr application on control of Japanese knotweed. Masters thesis. School of Forest Resources, College of Agricultural Sciences, Pennsylvania State University.					
Location	Disturbed forest clearings, Ridge and Valley physiographic province, Susquehanna River Basin, Pennsylvania, USA: site 1 in dry oak-mixed hardwood forest on power-line right-of-way in Rothrock State Forest, Centre County, south of State College off Route 26 on Kepler Road; site 2 in silver maple floodplain forest in Milton State Park, island on West Branch of Susquehanna River, Northumberland County, between Milton and West Milton.					
Subject	*Fallopia japonica* var. 'Crimson Beauty' (site 1) and *Fallopia x bohemica* (Bohemian knotweed) (site 2)					
Intervention	Foliar spraying of glyphosate, imazapyr at 2 dosages, and glyphosate + imazapyr at 2 dosages, with and without cutting & spraying of regrowth					
Methodology	Randomised Controlled Trial extracted as Site Comparison. A randomised split-plot design of 20 plots was replicated over three blocks on two sites. Treatments were applied to plots; each May plot was split into two sub-plots, one of which received a second application in August. One non-independent untreated control plot (3 sub-plots) was included. Each plot was 4 x 8m, May sub-plots were 4 x 4m. Herbicide or cutting was applied once in May; cut plots were sprayed once in June. Monitoring was conducted at 14 months after treatment.					
Data timescale	14 months					
Baseline comparison	No baseline information is presented.					
Replication	Three fully-replicated blocks per site at two sites, therefore three replications of treatments and control per site.					
Parameter of abundance	Number of stems					
Outcomes	Treatment			Control		
	n	m	sd	n	m	sd
Glyphosate (site 1)	3	95	17.32	3	61	19.31
Glyphosate (site 2)	3	23.33	17.5	3	46.67	6.03
Cut & spray glyphosate (site 1)	3	13.33	6.81	3	61	19.31

<table>
<tr><td>Cut & spray glyphosate (site 2)</td><td>3</td><td>52</td><td>25.71</td><td>3</td><td>46.67</td><td>6.03</td></tr>
<tr><td>Imazapyr (site 1)</td><td>3</td><td>11</td><td>5.29</td><td>3</td><td>61</td><td>19.31</td></tr>
<tr><td>Imazapyr (site 2)</td><td>3</td><td>13.33</td><td>11.93</td><td>3</td><td>46.67</td><td>6.03</td></tr>
<tr><td>Imazapyr & glyphosate (site 1)</td><td>3</td><td>9.67</td><td>6.69</td><td>3</td><td>61</td><td>19.31</td></tr>
<tr><td>Imazapyr & glyphosate (site 2)</td><td>3</td><td>16.33</td><td>13.58</td><td>3</td><td>46.67</td><td>6.03</td></tr>
<tr><td>Reasons for heterogeneity</td><td colspan="6">habitat type (disturbed forest clearings), temperature (?), rainfall (?), soil moisture (both well-drained), soil type (Kepler - Ungers very stony loam, Milton - Barbour), ground slope (Kepler - 8-25%, Milton - 0-3%), shading (?), latitude/longitude (?), altitude (Kepler - 55msl, Milton - 116msl), age of stand (?), height of stand (?), density of knotweed at start (?), size of controlled area (May treatments - 16m^2 per plot, controls and cut &spray - 32m^2 per plot), previous control (?), duration of control (11 months), effort of control (single), timing of control (herbicides May, cutting May then June herbicide), herbicide type (glyphosate, imazapyr, combination), herbicide application method (backpack sprayer), concentration of herbicide (glyphosate = 4kg ai/ha, imazapyr = 0.5kg ai/ha, combination = glyphosate 4 + imazapyr 0.5kg ai/ha), number of herbicide applications (one), mechanical techniques (cutting by machete on June sprayed site only), no. applications/cuts (one), type of grazer (N/A), hybridisation (N/A), species variety (var. <i>japonica</i>).</td></tr>
<tr><td>Extraction</td><td colspan="6">Raw before and after stem count data supplied by author were used to calculate means and standard deviations per treatment per site. Only data for May application of all herbicides was used, due to cutting preceding treatment in later months. Data for glyphosate treatment in June preceded by cutting in May was also used. Non-independent data extracted for controls within blocks, but as this was used in separate meta-analyses, it does not present a problem. Independent effect sizes were extractable for two sites. Imazapyr dose rate of 0.5kg ai/ha was used for both alone and combination applications. This was to maintain independence by using only a single effect size per study site, and this was rate was chosen as it was the most similar to the Figueroa study rate.</td></tr>
<tr><td>Sources of bias</td><td colspan="6">Timescale is short therefore do not know long-term effects of treatment. No data were presented regarding experimental blocks at start of trial, therefore there is no evidence that changes are related to interventions.</td></tr>
<tr><td>Notes</td><td colspan="6">Other data presented but not extracted related to: above ground biomass, height, number of new seedlings, and % cover of volunteer species.</td></tr>
<tr><td>References</td><td colspan="6">N/A</td></tr>
</table>

APPENDIX 6. REFERENCE LIST OF ARTICLES EXCLUDED FROM MULTIVARIATE SYNTHESIS

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APPENDIX 8. ABRIDGED DATA EXTRACTION TABLE USED IN THE DCA SYNTHESIS **(Abbreviations: RCT=Randomised controlled trial, CT=Controlled trial, SC=Site Comparison, TS=Time series, JAP=Japanese knotweed, BOH=Bohemian knotweed)**

Study	Duration of control (months)	Initial timing of control	Herbicide type	Herbicide application method	No. herbicide applications	Mechanical technique	No. mechanical applications	Species variety	Experimental design	Replication	Outcome
Ahrens A	12	June	glyphosate	spray	1	N/A	0	JAP	SC	2	effective
Ahrens B	12	June	glyphosate	spray	2	N/A	0	JAP	SC	2	very effective
Ahrens C	12	June	glyphosate	spray	1	N/A	0	JAP	SC	2	effective
Ahrens D	12	June	glyphosate	spray	2	N/A	0	JAP	SC	2	very effective
Ahrens E	12	June	glyphosate	spray	1	N/A	0	JAP	SC	2	effective
Ahrens F	12	June	glyphosate	spray	2	N/A	0	JAP	SC	2	very effective
McCormick A	14	June	clopyralid	spray	1	N/A	0	JAP	RCT	3	very ineffective
McCormick B	14	June	dicamba	spray	1	N/A	0	JAP	RCT	3	neutral
McCormick C	14	June	glyphosate A	spray	1	N/A	0	JAP	RCT	3	neutral
McCormick D	14	June	glyphosate B	spray	2	N/A	0	JAP	RCT	3	effective
McCormick E	14	June	imazapyr	spray	1	N/A	0	JAP	RCT	3	very effective
McCormick F	14	June	metsulfuron	spray	1	N/A	0	JAP	RCT	3	very ineffective
McCormick G	14	June	dicamba + clopyralid	spray	1	N/A	0	JAP	RCT	3	very ineffective
McCormick H	14	June	dicamba + imazapyr	spray	1	N/A	0	JAP	RCT	3	very ineffective
McNair A	21	March	N/A	N/A	0	dig & cut	2	JAP	RCT	4	ineffective

McNair B	21	March	glyphosate	spray	2	cutting	1	JAP	RCT	4	neutral
McNair C	21	March	glyphosate	spray	2	dig & cut	2	JAP	RCT	4	neutral
Soper	17	June	asulam	spray	1	N/A	0	JAP	snapshot	1	ineffective
Lichte A	17	June	2,4D	spray	1	N/A	0	JAP	snapshot	1	ineffective
Lichte B	17	June	2,4,5T	spray	1	N/A	0	JAP	snapshot	1	ineffective
Lichte C	17	June	picloram	spray	1	N/A	0	JAP	snapshot	1	very effective
Lichte D	12	June	ioxynil	spray	5	N/A	0	JAP	snapshot	1	very effective
Lichte E	12	June	bentazon	spray	5	N/A	0	JAP	snapshot	1	very effective
Hurle A	12	July	glyphosate	spray	2	N/A	0	JAP	SC	1	neutral
Hurle B	1.5	August	triclopyr	spray	1	N/A	0	JAP	SC	1	very effective
Hurle C	1.5	August	glyphosate	spray	1	N/A	0	JAP	SC	1	very effective
Gozart A	8	August	glyphosate	injection	1	N/A	0	BOH	TS	8	very effective
Gozart B	8	August	glyphosate	injection + spray	1	N/A	0	BOH	TS	3	very effective
Gozart C	8	August	imazapyr	spray	1	N/A	0	BOH	TS	9	very effective
Pauly A	3	June	glyphosate	spray	1	cutting	1	JAP	snapshot	1	very effective
Pauly B	17	June	2,4D	spray	1	N/A	0	JAP	snapshot	1	ineffective
Pauly C	17	June	N/A	N/A	0	cutting	3	JAP	snapshot	1	ineffective
Holowid B	14	April	glyphosate	spray	1	cutting	1	JAP	SC	3	very effective
McKeon	17	June	glyphosate	spray	2	digging	1	JAP	snapshot	1	very effective
dedeschmitt	12	March	N/A	N/A	0	cut & dig & geotextile & pull	4	JAP	snapshot	1	very effective

Bing	17	June	glyphosate	spray	1	N/A	0	JAP	snapshot	1	effective
Bricksfield A	17	June	N/A	N/A	0	dig & cut	3	JAP	snapshot	1	very effective
Bricksfield B	2	June	N/A	N/A	0	cutting	3	JAP	snapshot	1	effective
Beerling & Palmer	12	June	N/A	N/A	0	cutting	1	JAP	SC	3	very ineffective
Palmer et alA	4	May	dicamba + triclopyr + 2,4D	spray	1	N/A	0	JAP	SC	1	very effective
Palmer et alB	23	September	dicamba + triclopyr + 2,4D	spray	1	N/A	0	JAP	SC	1	very effective
Palmer et alC	10	August	dicamba + triclopyr + 2,4D	spray	1	N/A	0	JAP	SC	1	very effective
REC	6	June	N/A	N/A	0	root barrier	1	JAP	snapshot	1	very effective
Lynn	13	June	glyphosate	spray	1	N/A	0	JAP	TS	1	very effective
Roblin 88A	12	June	glyphosate	spray	1	N/A	0	JAP	SC	2	effective
Roblin 88B	12	August	glyphosate	spray	1	N/A	0	JAP	SC	2	neutral
Roblin 88C	12	September	glyphosate	spray	1	N/A	0	JAP	SC	2	very effective
Roblin 88D	12	June	glyphosate	spray	3	N/A	0	JAP	SC	2	very effective
Roblin 88E	12	August	glyphosate	spray	1	N/A	0	JAP	SC	2	effective
Roblin 88F	12	September	glyphosate	spray	1	N/A	0	JAP	SC	2	neutral
Roblin 88G	3	May	glyphosate	spray	1	N/A	0	JAP	snapshot	1	neutral
Roblin 88H	3	June	glyphosate	spray	1	N/A	0	JAP	snapshot	1	effective
Roblin 88I	3	July	glyphosate	spray	1	N/A	0	JAP	snapshot	1	effective
Roblin 88J	3	August	glyphosate	spray	1	N/A	0	JAP	snapshot	1	effective
Roblin 88K	3	July	glyphosate	spray	1	N/A	0	JAP	snapshot	2	effective
Roblin 88L	3	July	N/A	N/A	0	cutting	1	JAP	snapshot	1	very ineffective
Welsh WaterA	17	June	N/A	N/A	0	cutting	1	JAP	snapshot	1	very ineffective

Welsh WaterB	6	July	glyphosate	spray	1	N/A	0	JAP	SC	4	very effective
Welsh WaterC	8	May	dichlobenil	granules	1	N/A	0	JAP	SC	4	neutral
Baker A	1200	July	N/A	N/A	0	pulling	3	JAP	SC	1	effective
Baker B	36	July	N/A	N/A	0	pulling	3	JAP	snapshot	1	very effective
Baker C	24	June	N/A	N/A	0	cutting	3	JAP	snapshot	1	ineffective
Gover 2001a A	12	May	clopyralid + dicamba	spray	1	N/A	0	JAP	SC	1	ineffective
Gover 2001a B	12	May	clopyralid + glyphosate	spray	1	N/A	0	JAP	SC	1	ineffective
Gover 2001a C	12	May	clopyralid + picloram	spray	1	N/A	0	JAP	SC	1	ineffective
Gover 2000d	14	May	clopyralid + dicamba	spray	2	N/A	0	JAP	SC	3	very effective
Gover 2000b	15	April	clopyralid + glyphosate, glyphosate, dicamba + picloram + clopyralid	spray	3	N/A	0	JAP	snapshot	1	ineffective
Gover 2002 A	6	June	hexazinone	spray	1	N/A	0	JAP	SC	1	very ineffective
Gover 2002 B	6	June	glufosinate-ammonium	spray	1	N/A	0	JAP	SC	1	very ineffective
Gover 2002 C	6	June	N/A	N/A	0	cutting	1	JAP	SC	1	effective
Gover 2002 D	9	October	glyphosate	spray	1	N/A	0	JAP	snapshot	1	effective
Ford	72	September	glyphosate	fill + spray	6	cutting	1	JAP	snapshot	1	very effective
Deerfield A	36	April	N/A	N/A	0	cutting	9	JAP	snapshot	1	very effective

Deerfield B	36	July	N/A	N/A	0	pulling	3	JAP	snapshot	1	very effective
Doll	12	July	glyphosate	spray	1	dig & cut	2	JAP	snapshot	1	very effective
Hart A	12	June	picloram	spray	1	cutting	1	JAP	snapshot	1	neutral
Hart B	12	June	picloram	spray	1	cutting	1	JAP	snapshot	1	very effective
Thain A	15	February	tebuthiuron	pellets	1	N/A	0	JAP	SC	2	very effective
Skibo A	1	June	mesotrione + dicamba + atrazine	spray	1	cutting	1	JAP	RCT	3	very effective
Skibo B	1	June	mesotrione + dicamba + atrazine	spray	1	cutting	1	JAP	RCT	3	ineffective
Skibo C	1	June	mesotrione + dicamba + atrazine	spray	1	cutting	1	JAP	RCT	3	ineffective
Skibo D	1	June	mesotrione + dicamba + atrazine	spray	1	cutting	1	JAP	RCT	3	ineffective
Skibo E	1	June	Clopyralid & Nicosulfuron & Rimsulfuron & Flumetsulam + dicamba	spray	1	cutting	1	JAP	RCT	3	ineffective
Skibo F	1	June	carfentrazone-ethyl + atrazine + dicamba	spray	1	cutting	1	JAP	RCT	3	ineffective
Skibo G	1	June	Atrazine + Dicamba	spray	1	cutting	1	JAP	RCT	3	ineffective

Skibo H	1	June	Atrazine & Nicosulfuron & Rimsulfuron + dicamba	spray	1	cutting	1	JAP	RCT	3	ineffective
Skibo I	1	June	Atrazine & Nicosulfuron & Rimsulfuron + mesotrione	spray	1	cutting	1	JAP	RCT	3	ineffective
Skibo J	1	June	halosulfuron + dicamba	spray	1	cutting	1	JAP	RCT	3	ineffective
Skibo K	1	June	halosulfuron + dicamba	spray	1	cutting	1	JAP	RCT	3	ineffective
Skibo L	1	June	halosulfuron + dicamba	spray	1	cutting	1	JAP	RCT	3	ineffective
Skibo M	1	June	halosulfuron + dicamba	spray	1	cutting	1	JAP	RCT	3	ineffective
Skibo N	1	June	Primisulfuron-methyl + dicamba	spray	1	cutting	1	JAP	RCT	3	ineffective
Skibo O	1	June	Primisulfuron-methyl + dicamba + atrazine	spray	1	cutting	1	JAP	RCT	3	ineffective
Skibo P	1	June	Primisulfuron-methyl & Prosulfuron + dicamba	spray	1	cutting	1	JAP	RCT	3	ineffective
Skibo Q	1	June	Primisulfuron-methyl & Prosulfuron + dicamba + atrazine	spray	1	cutting	1	JAP	RCT	3	ineffective

Skibo R	1	June	Diflufenzopyr-sodium & Dicamba & Nicosulfuron	spray	1	cutting	1	JAP	RCT	3	ineffective
Skibo S	1	June	mesotrione + dicamba + atrazine	spray	1	cutting	1	JAP	RCT	3	ineffective
Skibo T	1	June	mesotrione + dicamba + atrazine	spray	1	cutting	1	JAP	RCT	3	ineffective
Skibo U	1	June	mesotrione + atrazine	spray	1	cutting	1	JAP	RCT	3	ineffective
Skibo V	1	June	mesotrione + atrazine	spray	1	cutting	1	JAP	RCT	3	ineffective
Skibo W	1	June	glyphosate + glyphosate & atrazine	spray	1	cutting	1	JAP	RCT	3	ineffective
Skibo X	1	June	glyphosate + glyphosate & atrazine	spray	1	cutting	1	JAP	RCT	3	ineffective
Skibo Y	1	June	glyphosate + glyphosate & atrazine	spray	1	cutting	1	JAP	RCT	3	ineffective
Burgess 2005b A	2	July	glyphosate	fill	1	cutting	1	JAP	TS	4	very effective
Burgess 2005b B	2	July	glyphosate	injection	1	N/A	0	JAP	TS	3	very effective
Burgess 2005b C	2	July	glyphosate	injection	1	N/A	0	JAP	TS	4	very effective
Burgess 2005a A	1.5	June	glyphosate	injection	1	N/A	0	BOH	TS	2	very effective
Burgess 2005a B	1.5	June	glyphosate	injection	1	N/A	0	BOH	TS	7	very effective

Figueroa A	11	June	clopyralid	spray	1	N/A	0	JAP	SC	2	effective
Figueroa B	11	June	clopyralid	spray	1	N/A	0	JAP	SC	2	ineffective
Figueroa C	11	June	clopyralid	spray	1	N/A	0	JAP	SC	2	ineffective
Figueroa D	11	June	clopyralid	spray	1	N/A	0	JAP	SC	2	neutral
Figueroa E	11	June	imazapyr	spray	1	N/A	0	JAP	SC	2	very effective
Figueroa F	11	June	dicamba	spray	1	N/A	0	JAP	SC	2	ineffective
Figueroa G	11	June	2,4D	spray	1	N/A	0	JAP	SC	2	very ineffective
Figueroa H	11	June	glyphosate	spray	1	N/A	0	JAP	SC	2	neutral
Figueroa I	17	June	metsulfuron	spray	1	N/A	0	JAP	SC	3	ineffective
Miller 2005A	11	July	glyphosate	injection	1	N/A	0	BOH	TS	4	effective
Miller 2005B	11	July	imazapyr	spray	1	N/A	0	BOH	TS	4	effective
Miller 2005C	11	July	glyphosate + imazapyr	spray	1	N/A	0	BOH	TS	4	very effective
Miller 2005D	11	July	glyphosate + imazapyr	spray	1	N/A	0	BOH	TS	4	effective
Miller 2005E	11	July	glyphosate	injection	1	N/A	0	JAP	TS	8	effective
Env Agency C	17	June	N/A	N/A	0	habitat manipulation	1	JAP	snapshot	1	effective
Env Agency D	17	June	glyphosate	spray	1	N/A	0	JAP	snapshot	1	effective
Env Agency E	17	June	2,4D	spray	1	N/A	0	JAP	snapshot	1	neutral
Env Agency G	17	June	N/A	N/A	0	grazing	1	JAP	snapshot	1	effective
Beerling 1991d	17	June	N/A	N/A	0	grazing	1	JAP	snapshot	44	very effective
Harranger A	12	June	glphosate	spray	1	N/A	0	JAP	snapshot	1	effective
Harranger B	12	June	triclopyr	spray	1	N/A	0	JAP	snapshot	1	neutral
Harranger C	24	June	glphosate	spray	2	N/A	0	JAP	snapshot	1	very effective

Harranger D	24	June	triclopyr	spray	2	N/A	0	JAP	snapshot	1	neutral
Boquet A	6	June	triclopyr, glyphosate + 2,4-D / 2,4-DP-P / MCPP-P, glyphosate	spray	3	cutting	2	JAP	TS	1	neutral
Boquet B	6	June	N/A	N/A	0	cut + tarp	2	JAP	TS	1	effective
Boquet C	6	June	triclopyr + glyphosate, glyphosate twice	spray	3	cutting	1	JAP	TS	1	neutral
Boquet D	6	June	triclopyr, 2,4-D / 2,4-DP-P / MCPP-P	spray	2	cutting	1	JAP	TS	1	neutral
Boquet E	6	June	triclopyr, glyphosate twice	spray	3	cutting	2	JAP	TS	1	neutral
Boquet F	6	June	triclopyr + glyphosate, glyphosate twice	spray	3	cutting	1	JAP	TS	1	neutral
Boquet G	6	June	triclopyr, glyphosate	spray	2	cut + tarp	3	JAP	TS	1	effective
Boquet H	5	July	triclopyr	fill	1	cutting	1	JAP	snapshot	1	very effective
Boquet I	17	June	N/A	N/A	0	dig & till & cardboard	3	JAP	snapshot	2	very effective
Nashiki	17	June	N/A	N/A	0	grazing	1	JAP	snapshot	138	ineffective
Scott A	12	August	N/A	N/A	0	cutting	1	JAP	snapshot	1	very ineffective
Scott B	24	April	N/A	N/A	0	cutting	12	JAP	snapshot	1	ineffective
Sewak 2005b	36	May	glyphosate	spray	6	N/A	0	JAP	TS	1	very effective
Sewak 2005a A	12	May	glyphosate	spray	2	N/A	0	JAP	snapshot	8	ineffective

Sewak 2005a B	12	June	glyphosate	spray	1	cutting	1	JAP	snapshot	9	neutral
Sewak 2005a D	12	June	N/A	N/A	0	digging	1	JAP	snapshot	1	ineffective
Marion CtyA	7	April	N/A	N/A	0	cutting	1	JAP	snapshot	22	neutral
Marion CtyB	7	April	triclopyr + glyphosate	wipe	1	N/A	0	JAP	snapshot	1	very effective
Marion CtyC	7	April	triclopyr + glyphosate	wipe	1	cutting	1	JAP	snapshot	20	effective
Roblin 1994	17	June	2,4D	spray	1	N/A	0	JAP	snapshot	1	neutral
Child A	37	May	glyphosate	spray	2	cutting	1	JAP	SC	1	effective
Child B	37	October	glyphosate	spray	2	dig & cut	2	JAP	SC	2	very effective
Child C	37	June	N/A	N/A	0	cutting	1	JAP	SC	1	effective
Child D	37	October	N/A	N/A	0	dig & cut	2	JAP	SC	1	effective
Child E	37	October	glyphosate	spray	1	dig & cut	2	JAP	SC	1	neutral
De Waal A	14	June	glyphosate	spray	2	N/A	0	JAP	SC	2	very effective
De Waal B	14	June	glyphosate	spray	1	cutting	1	JAP	SC	2	very effective
De Waal C	13	July	N/A	N/A	0	cutting	1	JAP	SC	1	effective
De Waal D	12	August	N/A	N/A	0	cutting	1	JAP	SC	1	effective
De Waal E	22	July	glyphosate	spray	1	N/A	0	JAP	SC	1	very effective
Scott&Marrs A	15	May	picloram	spray	1	N/A	0	JAP	RCT	3	very effective
Scott&Marrs B	15	May	picloram	spray	2	N/A	0	JAP	RCT	3	very effective
Scott&Marrs C	15	May	ammonium sulphamate	spray	1	N/A	0	JAP	RCT	3	neutral
Scott&Marrs D	15	May	ammonium sulphamate	spray	2	N/A	0	JAP	RCT	3	effective

Scott&Marrs E	15	May	triclopyr	spray	1	N/A	0	JAP	RCT	3	neutral
Scott&Marrs F	15	May	triclopyr	spray	2	N/A	0	JAP	RCT	3	neutral
Scott&Marrs G	15	May	tebuthiuron	spray	1	N/A	0	JAP	RCT	3	neutral
Scott&Marrs H	15	May	tebuthiuron	spray	2	N/A	0	JAP	RCT	3	neutral
Scott&Marrs I	15	May	simazine	spray	1	N/A	0	JAP	RCT	3	very ineffective
Scott&Marrs J	15	May	simazine	spray	2	N/A	0	JAP	RCT	3	neutral
Scott&Marrs K	15	May	asulam	spray	1	N/A	0	JAP	RCT	3	ineffective
Scott&Marrs L	15	May	asulam	spray	2	N/A	0	JAP	RCT	3	ineffective
Scott&Marrs M	15	May	glyphosate	spray	1	N/A	0	JAP	RCT	3	very ineffective
Scott&Marrs N	15	May	glyphosate	spray	2	N/A	0	JAP	RCT	3	ineffective
Scott&Marrs O	15	May	fosamine	spray	1	N/A	0	JAP	RCT	3	very ineffective
Scott&Marrs P	15	May	fosamine	spray	2	N/A	0	JAP	RCT	3	very ineffective
Scott&Marrs Q	15	May	atrazine + aminotriazole	spray	1	N/A	0	JAP	RCT	3	neutral
Scott&Marrs R	15	May	atrazine + aminotriazole	spray	2	N/A	0	JAP	RCT	3	very ineffective
Scott&Marrs S	15	May	N/A	N/A	0	cutting	1	JAP	RCT	3	effective
Scott&Marrs T	15	May	N/A	N/A	0	cutting	2	JAP	RCT	3	very ineffective
Soll A	36	April	N/A	N/A	0	cutting	18	JAP	snapshot	3	ineffective
Soll B	17	June	glyphosate	spray	1	N/A	0	JAP	snapshot	1	neutral

Soll C	17	June	glyphosate + triclopyr	spray	1	N/A	0	JAP	snapshot	1	neutral
Long Ashton A	13	June	2,4D	spray	1	N/A	0	JAP	SC	3	very ineffective
Long Ashton B	13	June	imazamethabenz-methyl	spray	1	N/A	0	JAP	SC	3	very ineffective
Long Ashton C	13	June	clopyralid	spray	1	N/A	0	JAP	SC	3	neutral
Long Ashton D	13	June	amidosulfuron	spray	1	N/A	0	JAP	SC	3	very ineffective
Long Ashton E	13	June	propaquizafop	spray	1	N/A	0	JAP	SC	3	effective
Long Ashton F	13	June	metazachlor + quinmerac	spray	1	N/A	0	JAP	SC	3	very ineffective
Long Ashton G	13	June	carfentrazone + flupyrsulfuron	spray	1	N/A	0	JAP	SC	3	neutral
Long Ashton H	13	June	fluroxypyr	spray	1	N/A	0	JAP	SC	3	very effective
Long Ashton I	13	June	triclopyr	spray	1	N/A	0	JAP	SC	3	very effective
Silver A	17	June	glyphosate	spray	1	N/A	0	JAP	snapshot	1	very effective
Silver B	17	June	glyphosate	spray	1	N/A	0	JAP	snapshot	1	very effective
Natural BiodiversityA	48	May	glyphosate	spray	8	N/A	0	JAP	TS	1	very effective
Natural BiodiversityB	12	June	glyphosate	spray	1	cutting	1	JAP	TS	1	very effective
Lackey A	24	June	N/A	N/A	0	dig & tarp & pull/cut	3	JAP	snapshot	1	neutral
Lackey B	24	June	N/A	N/A	0	burial	1	JAP	snapshot	1	very effective
Crockett A	17	June	glyphosate + imazapyr	spray	1	N/A	0	JAP	snapshot	1	very effective

Crockett B	17	June	triclopyr	spray	1	N/A	0	JAP	snapshot	1	neutral
Crockett C	17	June	glyphosate	injection	1	N/A	0	JAP	snapshot	1	very effective
Crockett D	21	June	glyphosate + imazapyr	fill	1	cutting	1	JAP	snapshot	1	very effective
Miller 2004A	4	April	glyphosate	spray	1	cutting	2	BOH	RCT	4	very effective
Miller 2004B	4	April	glyphosate	spray	1	cutting	2	BOH	RCT	4	very effective
Miller 2004C	4	April	triclopyr	spray	1	cutting	2	BOH	RCT	4	very effective
Miller 2004D	4	April	triclopyr	spray	1	cutting	2	BOH	RCT	4	very effective
Miller 2004E	4	April	imazapyr	spray	1	cutting	2	BOH	RCT	4	very effective
Miller 2004F	4	April	imazapyr	spray	1	cutting	2	BOH	RCT	4	very effective
Miller 2004G	4	April	glyphosate + triclopyr + imazapyr	spray	1	cutting	2	BOH	RCT	4	very effective
Miller 2004H	4	April	glyphosate + imazapyr	spray	1	cutting	2	BOH	RCT	4	very effective
Miller 2004I	4	April	triclopyr + imazapyr	spray	1	cutting	2	BOH	RCT	4	very effective
Miller 2004J	4	April	glyphosate + triclopyr + imazapyr	spray	1	cutting	2	BOH	RCT	4	very effective
Miller 2004K	4	April	imazapic	spray	1	cutting	2	BOH	RCT	4	very effective
Miller 2004L	4	April	imazapic	spray	1	cutting	2	BOH	RCT	4	very effective
Miller 2004M	12	August	glyphosate	wipe	1	N/A	0	BOH	RCT	4	effective
Miller 2004N	10	September	glyphosate	wipe	1	N/A	0	BOH	RCT	4	effective

Miller 2004O	12	August	glyphosate	wipe	1	cutting	1	BOH	RCT	4	very effective
Miller 2004P	10	September	glyphosate	wipe	1	cutting	1	BOH	RCT	4	very effective
Miller 2004Q	12	August	glyphosate	injection	1	N/A	0	BOH	RCT	4	very effective
Miller 2004R	10	September	glyphosate	injection	1	N/A	0	BOH	RCT	4	very effective
Miller 2004S	12	August	glyphosate	injection	1	N/A	0	BOH	RCT	4	very effective
Miller 2004T	10	September	glyphosate	injection	1	N/A	0	BOH	RCT	4	very effective
Miller 2004U	12	August	triclopyr	wipe	1	N/A	0	BOH	RCT	4	effective
Miller 2004V	10	September	triclopyr	wipe	1	N/A	0	BOH	RCT	4	effective
Miller 2004W	12	August	triclopyr	wipe	1	cutting	1	BOH	RCT	4	very effective
Miller 2004X	10	September	triclopyr	wipe	1	cutting	1	BOH	RCT	4	very effective
Miller 2004Y	12	August	triclopyr	injection	1	N/A	0	BOH	RCT	4	very effective
Miller 2004Z	10	September	triclopyr	injection	1	N/A	0	BOH	RCT	4	very effective
Miller 2004AA	12	August	triclopyr	injection	1	N/A	0	BOH	RCT	4	very effective
Miller 2004BB	10	September	triclopyr	injection	1	N/A	0	BOH	RCT	4	very effective
Miller 2004CC	12	August	imazapyr	wipe	1	N/A	0	BOH	RCT	4	effective
Miller 2004DD	10	September	imazapyr	wipe	1	N/A	0	BOH	RCT	4	effective
Miller 2004EE	12	August	imazapyr	wipe	1	cutting	1	BOH	RCT	4	very effective
Miller 2004FF	10	September	imazapyr	wipe	1	cutting	1	BOH	RCT	4	very effective

Miller 2004GG	12	August	imazapyr	injection	1	N/A	0	BOH	RCT	4	very effective
Miller 2004HH	10	September	imazapyr	injection	1	N/A	0	BOH	RCT	4	very effective
Miller 2004II	12	August	imazapyr	injection	1	N/A	0	BOH	RCT	4	very effective
Miller 2004JJ	10	September	imazapyr	injection	1	N/A	0	BOH	RCT	4	very effective
Kister A	17	May	aminotriazole + isoxaben + glyphosate	spray	2	N/A	0	JAP	SC	1	very effective
Kister B	17	May	aminotriazole + isoxaben + dichlorprop p + glyphosate	spray	2	N/A	0	JAP	SC	1	very effective
Kister C	17	May	aminotriazole + isoxaben + sulfosate	spray	2	N/A	0	JAP	SC	1	very effective
Kister D	17	May	aminotriazole + isoxaben + 2,4D + triclopyr	spray	2	N/A	0	JAP	SC	1	effective
Kister E	17	May	flazasulfuron + glyphosate	spray	2	N/A	0	JAP	SC	1	effective
Kister F	17	May	flazasulfuron + dichlorprop p + glyphosate	spray	2	N/A	0	JAP	SC	1	effective
Kister G	17	May	flazasulfuron + sulfosate	spray	2	N/A	0	JAP	SC	1	very effective
Kister H	17	May	flazasulfuron + 2,4D + triclopyr	spray	2	N/A	0	JAP	SC	1	neutral
Kister I	12	June	N/A	N/A	0	root barrier	1	JAP	SC	1	ineffective
Kister J	3	June	N/A	N/A	0	burning	6	JAP	SC	1	neutral

Harper A	12	April	N/A	N/A	0	crushing	2	JAP	snapshot	1	very ineffective
Harper B	17	June	amitrole-T	spray	1	N/A	0	JAP	snapshot	1	ineffective
Harper C	17	June	2,4,5-T + 2,4D	spray	1	N/A	0	JAP	snapshot	1	ineffective
Harper D	17	June	2,4,5-T + 2,4D	spray	2	N/A	0	JAP	snapshot	1	ineffective
Harper E	17	June	2,4,5-T + 2,4D	spray	1	N/A	0	JAP	snapshot	1	ineffective
Harper F	17	June	2,4,5-T + 2,4D	spray	2	N/A	0	JAP	snapshot	1	ineffective
Harper G	17	June	2,4,5-T + 2,4D + diesel oil	spray	1	N/A	0	JAP	snapshot	1	ineffective
Harper H	35	June	bromacil, picloram	granules	2	N/A	0	JAP	SC	1	very ineffective
Harper I	35	June	bromacil, picloram	granules	2	N/A	0	JAP	SC	1	very effective
Harper J	35	June	bromacil, picloram	spray	2	N/A	0	JAP	SC	1	very effective
Harper K	36	June	bromacil	spray	2	N/A	0	JAP	SC	1	very effective
Harper L	23	June	2,4,5-T + 2,4D + diesel oil, picloram	spray	2	N/A	0	JAP	SC	1	neutral
Harper M	29	June	2,4,5-T + 2,4D + diesel oil, picloram	spray	2	N/A	0	JAP	SC	1	very effective
Harper N	11	June	picloram	spray	1	N/A	0	JAP	SC	1	neutral
Stingelin KeeferA	14	May	glyphosate	spray	1	N/A	0	JAP	RCT	6	very ineffective
Stingelin KeeferB	14	May	imazapyr	spray	1	N/A	0	JAP	RCT	6	effective
Stingelin KeeferC	14	May	imazapyr	spray	1	N/A	0	JAP	RCT	6	effective
Stingelin KeeferD	14	May	glyphosate + imazapyr	spray	1	N/A	0	JAP	RCT	6	neutral

Stingelin KeeferE	14	May	glyphosate + imazapyr	spray	1	N/A	0	JAP	RCT	6	very effective
Stingelin KeeferF	13	June	glyphosate	spray	1	cutting	1	JAP	RCT	6	neutral
Stingelin KeeferG	13	June	imazapyr	spray	1	cutting	1	JAP	RCT	6	neutral
Stingelin KeeferH	13	June	imazapyr	spray	1	cutting	1	JAP	RCT	6	effective
Stingelin KeeferI	13	June	glyphosate + imazapyr	spray	1	cutting	1	JAP	RCT	6	effective
Stingelin KeeferJ	13	June	glyphosate + imazapyr	spray	1	cutting	1	JAP	RCT	6	very effective
Stingelin KeeferK	12	July	glyphosate	spray	1	cutting	1	JAP	RCT	6	effective
Stingelin KeeferL	12	July	imazapyr	spray	1	cutting	1	JAP	RCT	6	effective
Stingelin KeeferM	12	July	imazapyr	spray	1	cutting	1	JAP	RCT	6	very effective
Stingelin KeeferN	12	July	glyphosate + imazapyr	spray	1	cutting	1	JAP	RCT	6	very effective
Stingelin KeeferO	12	July	glyphosate + imazapyr	spray	1	cutting	1	JAP	RCT	6	very effective
Stingelin KeeferP	11	August	glyphosate	spray	1	cutting	1	JAP	RCT	6	ineffective
Stingelin KeeferQ	11	August	imazapyr	spray	1	cutting	1	JAP	RCT	6	effective
Stingelin KeeferR	11	August	imazapyr	spray	1	cutting	1	JAP	RCT	6	very effective
Stingelin KeeferS	11	August	glyphosate + imazapyr	spray	1	cutting	1	JAP	RCT	6	ineffective
Stingelin KeeferT	11	August	glyphosate + imazapyr	spray	1	cutting	1	JAP	RCT	6	very effective

Stingelin KeeferU	14	May	glyphosate	spray	2	cutting	1	JAP	RCT	6	very effective
Stingelin KeeferV	14	May	imazapyr	spray	2	cutting	1	JAP	RCT	6	very effective
Stingelin KeeferW	14	May	imazapyr	spray	2	cutting	1	JAP	RCT	6	very effective
Stingelin KeeferX	14	May	glyphosate + imazapyr	spray	2	cutting	1	JAP	RCT	6	very effective
Stingelin KeeferY	14	May	glyphosate + imazapyr	spray	2	cutting	1	JAP	RCT	6	very effective
Seiger A	5.5	June	N/A	N/A	0	cutting	1	JAP	RCT	30	neutral
Seiger B	5.5	July	N/A	N/A	0	cutting	1	JAP	RCT	30	neutral
Seiger C	5.5	August	N/A	N/A	0	cutting	1	JAP	RCT	30	neutral
Seiger D	5.5	June	N/A	N/A	0	cutting	2	JAP	RCT	30	effective
Seiger E	5.5	June	N/A	N/A	0	cutting	2	JAP	RCT	30	effective
Seiger F	5.5	July	N/A	N/A	0	cutting	2	JAP	RCT	30	effective
Seiger G	5.5	June	N/A	N/A	0	cutting	3	JAP	RCT	30	very effective
Bimova A	17	May	N/A	N/A	0	cutting	2	JAP	CT	4	ineffective
Bimova B	17	May	N/A	N/A	0	digging	2	JAP	CT	4	very ineffective
Bimova C	17	May	glyphosate	spray	2	cutting	2	JAP	CT	4	effective
Bimova D	17	May	glyphosate	spray	2	digging	2	JAP	CT	4	neutral
Bimova E	17	May	N/A	N/A	0	cutting	2	BOH	CT	4	very ineffective
Bimova F	17	May	N/A	N/A	0	digging	2	BOH	CT	4	very ineffective
Bimova G	17	May	glyphosate	spray	2	cutting	2	BOH	CT	4	very effective
Bimova H	17	May	glyphosate	spray	2	digging	2	BOH	CT	4	effective
Beerling 1990A	2.5	May	glyphosate	spray	1	N/A	0	JAP	RCT	4	effective

Beerling 1990B	2.5	May	glyphosate	spray	2	N/A	0	JAP	RCT	4	very effective
Beerling 1990C	2.5	May	2,4D	spray	2	N/A	0	JAP	RCT	4	very effective
Adler	5	June	N/A	N/A	0	cutting	3	JAP	snapshot	1	effective
Brabec A	27	May	N/A	N/A	0	cutting	2	JAP	RCT	6	very effective
Brabec B	27	May	N/A	N/A	0	grazing	4	JAP	RCT	12	very effective
Brabec C	17	May	N/A	N/A	0	cutting	2	BOH	RCT	6	very effective
Brabec D	17	May	N/A	N/A	0	grazing	4	BOH	RCT	12	very effective
Joy A	32	September	2,4D	fill	1	cutting	1	JAP	SC	1	neutral
Joy B	32	September	2,4D, diquat, glyphosate	fill	3	cutting	3	JAP	SC	1	very effective
Joy C	32	September	asulam, diquat, glyphosate	fill	3	cutting	3	JAP	SC	1	very effective
Joy D	32	September	asulam, glyphosate twice	fill	3	cutting	3	JAP	SC	1	very effective
Joy E	32	September	asulam, imazapyr twice	fill	3	cutting	3	JAP	SC	1	very effective
Joy F	32	September	glyphosate	fill	3	cutting	3	JAP	SC	9	very effective
Joy G	32	September	glyphosate	fill	2	cutting	2	JAP	SC	1	neutral
Joy H	32	September	glyphosate twice, imazapyr	fill	3	cutting	3	JAP	SC	1	very effective
Joy I	32	September	picloram	fill	3	cutting	3	JAP	SC	1	very effective
Joy J	32	September	picloram, glyphosate twice	fill	3	cutting	3	JAP	SC	1	very effective
Joy K	32	September	triclopyr, glyphosate twice	fill	3	cutting	3	JAP	SC	2	very effective

Palmer A	17	June	glyphosate	spray	1	N/A	0	JAP	snapshot	12	effective
Palmer B	17	June	asulam	spray	1	N/A	0	JAP	snapshot	1	ineffective
Palmer C	17	June	2,4D	spray	1	N/A	0	JAP	snapshot	1	ineffective
Palmer D	17	June	triclopyr	spray	1	N/A	0	JAP	snapshot	4	effective
Palmer E	17	June	picloram	spray	1	N/A	0	JAP	snapshot	5	effective
Palmer F	17	June	2,4D + mecoprop	spray	1	N/A	0	JAP	snapshot	1	effective
Palmer G	17	June	2,4D + dicamba	spray	1	N/A	0	JAP	snapshot	2	ineffective
Palmer H	17	June	2,4D + triclopyr + dicamba	spray	1	N/A	0	JAP	snapshot	2	neutral
Palmer I	17	June	triclopyr + dicamba + mecoprop	spray	1	N/A	0	JAP	snapshot	3	ineffective
Palmer J	17	June	sodium chlorate	spray	1	N/A	0	JAP	snapshot	4	effective
Palmer K	17	June	atrazine + 2,4D + sodium chlorate	spray	1	N/A	0	JAP	snapshot	1	ineffective
Palmer L	17	June	amitrole + atrazine + diuron	spray	1	N/A	0	JAP	snapshot	2	neutral
Palmer M	17	June	paraquat	spray	1	N/A	0	JAP	snapshot	2	neutral
Palmer N	17	June	bentazone + MCPB	spray	1	N/A	0	JAP	snapshot	1	ineffective
Palmer O	17	June	monolinuron	spray	1	N/A	0	JAP	snapshot	1	ineffective
Palmer P	17	June	imazapyr	spray	1	N/A	0	JAP	snapshot	1	effective
Palmer Q	17	June	fluroxypyr	spray	1	N/A	0	JAP	snapshot	1	effective
Palmer R	17	June	N/A	N/A	0	cutting	1	JAP	snapshot	6	ineffective
Palmer S	17	June	N/A	N/A	0	dig & cut	1	JAP	snapshot	3	neutral
Palmer T	17	June	N/A	N/A	0	digging	1	JAP	snapshot	1	effective
Palmer U	17	June	N/A	N/A	0	pulling	1	JAP	snapshot	3	neutral